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THE ASTRONOMICAL OBSERVATORY

OF

HARVARD COLLEGE

HARLOW SHAPLEY, DIRECTOR



CIRCULARS

201 TO 250

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HARVARD COLLEGE OBSERVATORY.

CIRCULAR 201.

TWENTY-ONE NEW VARIABLE STARS.

A LIST of new variable stars found by various observers conducting investigations on the Harvard photographs, is given in Table I. Two are included which were found visually by Mr. Leon Campbell. The successive columns give the designation, the number in the series of variable stars discovered at this Observatory, the constellation, the Durchmusterung number, the approximate right ascension for 1900, the approximate declination for 1900, the observed photographic magnitudes of the brightest and faintest image so far observed, the class of the variation whenever determined, and the discoverer.

TABLE I.
NEW VARIABLE STARS.

Des.	H. V.	Constellation.	DM.	R.A. 1900.	Dec. 1900.	Bright.	Faint.	Class.	Discoverer.
				<i>h. m. s.</i>	<i>° ' "</i>				
015654	3414	Perseus	444	1 56.5	+54 45	9.6	10.4	..	I. E. Woods
042418	3415	Taurus	736	4 24.2	+18 0	11.2	13.3	IV	H. Locke
061925	3416	Gemini	..	6 19.8	+25 36	11.5	15.0	..	J. C. Mackie
065916	3417	Canis Major	..	6 59.9	-16 27	11.7	<15.3	..	M. E. O'Reilly
101349	3418	Vela	5125	10 13.5	-49 35	12.0	<14.0	..	L. D. Wells
122525	3419	Hydra	..	12 25.2	-25 30	10.3	11.7	IV	J. H. Metcalf
123054	3420	Centaurus	..	12 30.2	-54 1	12.5	<14.3	..	L. Campbell
133926	3421	Hydra	9905	13 39.0	-26 23	8.6	12.7	V	I. E. Woods
143719	3422	Libra	..	14 37.1	-19 47	10.0	<14.5	..	I. E. Woods
153037	3423	Lupus	10372	15 30.4	-37 31	11.3	<12.0	..	J. C. Mackie
155323	3424	Scorpius	..	15 53.5	-23 29	11.2	<15.0	..	J. C. Mackie
162618	3425	Hercules	3186	16 26.2	+18 36	9.5	11.5	IV	S. Raymond
164829	3426	Ophiuchus	..	16 48.4	-29 0	12.0	13.0	..	J. C. Mackie
170107	3427	Ophiuchus	3302	17 1.8	+ 7 55	9.1	10.1	..	J. H. Metcalf
170916	3428	Hercules	3130	17 9.5	+16 29	8.4	8.8	..	J. H. Metcalf
184202	3429	Aquila	4745	18 42.5	- 2 7	11.4	11.9	..	M. E. O'Reilly
184811	3430	Aquila	3649	18 48.2	+11 34	10.3	12.1	..	J. C. Mackie
185401	3431	Aquila	..	18 54.9	- 1 42	12.2	<16.0	..	M. E. O'Reilly
191219	3432	Sagittarius	..	19 12.8	-19 14	13.0	<14.0	..	L. Campbell
192229	3433	Sagittarius	..	19 22.7	-29 53	11.6	<13.3	..	J. C. Mackie
220100	3434	Aquarius	..	22 1.5	- 0 54	10.4	10.9	..	J. C. Mackie

REMARKS.

015654. The variability was confirmed by an examination of 520 photographs, taken between December 1, 1887 and February 4, 1913.
042418. This is a variable star of short period. Observations on three pairs of blue and yellow plates taken one after another give a color index of about one magnitude.
122525. The light of this star was measured by Miss Raymond on 292 photographs taken between April 22, 1892 and June 6, 1916. The formula for maxima is $J. D. 2416800.6 + 0^d.4786$.
133926. This star was measured by Miss Woods on 537 photographs taken between June 4, 1889 and March 26, 1917. The variation is of the Algol type. The formula for minima is $J. D. 2410001.2233 + 2^d.89570$.
162618. This star was measured by Miss Raymond on 350 photographs and the approximate period is $0^d.365$.
170107. Probably of the Algol type. It is faint on only 2 of 37 plates examined, taken between May 5, 1904 and July 30, 1915.
170916. The variation, which is small, was confirmed by Miss Leavitt and Miss Maekie.
184202. Observations on two pairs of blue and yellow plates taken one after another give a color index of 1.8 magn.
185401. Observations on two pairs of blue and yellow plates taken one after another show that the color index is not less than two magnitudes. The variable is not seen on either blue plate. The range observed on yellow plates is from 9.4 to 12.2. Comparing this with the range on blue plates as given in Table I, it appears probable that the color index is three magnitudes, or more.

EDWARD C. PICKERING.

JULY 12, 1917.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 202.

MAXIMA IN 1918 OF VARIABLE STARS OF LONG PERIOD.

As the changes in light of variable stars of long period are not regular, it is impossible to predict the times of maxima with accuracy. In H.C. 197, Mr. Leon Campbell predicted the times of maxima in 1917, by adding the approximate period to the times of recent maxima. The results of a similar determination for 1918 are given in Table I. The designation of the star in hours and minutes of right ascension and degrees of declination is given in the first column. The designation of the star according to the notation of Argelander is given in the second column. The date of the predicted maximum is given in the third column.

TABLE I.
PREDICTED MAXIMA.

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1918.			1918.			1918.
001046	X Androm.	Feb. 16	010940	U Androm.	Oct. 1	021024	R Arietis	Oct. 6
001726	T " "	" 6	011041	UZ " "	Jan. 4	021143a	W Androm.	May 17
"	" " "	Nov. 11	"	" " "	Nov. 13	021281	Z Cephei	June 15
001755	T Cassiop.	Sept. 15	011208	S Piscium	Mar. 11	021403	o Ceti	Sept. 4
001838	R Androm.	" 6	011272	S Cassiop.	July 23	022000	R " "	Apr. 17
001909	S Ceti	July 19	011712	U Piscium	Jan. 7	"	" " "	Sept. 30
003178	Y Cephei	Sept. 8	"	" " "	July 4	022150	RR Persei	Nov. 13
004047	U Cassiop.	Feb. 20	"	" " "	Dec. 29	022813	U Ceti	May 31
"	" " "	Nov. 26	012350	RZ Persei	Apr. 27	023080	RR Cephei	Apr. 4
004132	RW Androm.	Dec. 31	012502	R Piscium	Sept. 8	023133	R Trianguli	June 1
004435	V " "	Jan. 26	013238	RU Androm.	May 18	030514	U Arietis	Apr. 1
"	" " "	Oct. 13	013338	Y " "	Mar. 21	031401	X Ceti	" 11
004533	RR " "	July 12	"	" " "	Nov. 2	"	" " "	Oct. 3
004746	RV Cassiop.	May 30	014958	X Cassiop.	June 7	032043	Y Persei	June 13
004958	W " "	Oct. 20	015354	U Persei	Aug. 20	032335	R " "	Feb. 27
010102	Z Ceti	Apr. 7	015912	S Arietis	Sept. 8	"	" " "	Sept. 27
"	" " "	Oct. 10	021024	R " "	Apr. 3	042209	R Tauri	Mar. 16

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1918.			1918.			1918.
042215	W Tauri	June 21	072708	S Can. Min.	Oct. 3	124606	U Virginis	Jan. 0
042309	S "	Apr. 17	072811	T "	July 29	" "	" "	July 23
043065	T Camelop.	May 4	072820b	Z Puppis	Mar. 7	130212	RV "	" 20
043208	RX Tauri	Oct. 9	073508	U Can. Min.	Apr. 22	132202	V "	May 18
043274	X Camelop.	Mar. 9	073723	S Gemin.	Jan. 16	132422	R Hydrae	Oct. 23
" "	" "	July 29	" "	" "	Nov. 2	132706	S Virginis	Jan. 30
" "	" "	Dec. 18	074323	T "	Mar. 5	133273	T Urs. Min.	Apr. 16
044617	V Tauri	Apr. 13	" "	" "	Dec. 18	133440	R Can. Ven.	Oct. 3
" "	" "	Sept. 30	075612	U Puppis	Mar. 12	135908	RR Virginis	Jan. 7
045307	R Orionis	Apr. 21	081112	R Caneri	May 30	" "	" "	Aug. 11
045514	R Leporis	Feb. 7	081617	V "	" 18	140118	Z Bootis	Apr. 27
050003	V Orionis	Apr. 7	083019	U "	Apr. 7	140512	Z Virginis	May 13
" "	" "	Dec. 31	083350	X Urs. Maj.	July 5	141567	U Urs. Min.	Aug. 25
050022	T Leporis	Jan. 16	084803	S Hydrae	Jan. 23	141954	S Bootis	Jan. 17
050953	R Aurigae	Dec. 6	" "	" "	Oct. 7	" "	" "	Oct. 19
052036	W "	Sept. 5	085008	T "	Apr. 19	142205	RS Virginis	May 20
052404	S Orionis	Feb. 21	090024	S Pyxidis	" 16	142539	V Bootis	Sept. 5
053068	S Camelop.	July 7	" "	" "	Nov. 12	142584	R Camelop.	Aug. 26
053531	U Aurigae	No Max.	090425	W Caneri	Aug. 12	143227	R Bootis	Apr. 25
054920	U Orionis	June 29	093014	X Hydrae	July 24	" "	" "	Dec. 4
054974	V Camelop.	July 12	093178	Y Draconis	Mar. 18	143417	V Librae	Apr. 24
055353	Z Aurigae	Jan. 8	093934	R Leo. Min.	Feb. 13	" "	" "	Oct. 1
" "	" "	Apr. 30	094023	RR Hydrae	" 27	144918	U Bootis	Mar. 17
" "	" "	Aug. 20	094211	R Leonis	June 19	" "	" "	Sept. 3
" "	" "	Dec. 10	095421	V "	Mar. 5	160018	RT Librae	Feb. 2
060450	X "	Mar. 19	" "	" "	Dec. 3	" "	" "	Oct. 13
" "	" "	Aug. 28	103769	R Urs. Maj.	June 13	150519	T "	Jan. 14
061647	V "	Dec. 25	104814	W Leonis	Dec. 16	" "	" "	Sept. 12
061702	V Monoc.	Oct. 9	110506	S "	Jan. 26	150605	Y "	May 6
063159	U Lynceis	No Max.	" "	" "	Aug. 4	151520	S "	Feb. 15
063558	S "	July 2	115919	R Comae	June 11	" "	" "	Aug. 26
064030	X Gemin.	Jan. 0	120012	SU Virginis	Jan. 12	151714	S Serpents	" 17
" "	" "	Sept. 21	" "	" "	Aug. 4	151731	S Cor. Bor.	Feb. 10
064707	W Monoc.	Mar. 15	120905	T "	Jan. 28	151822	RS Librae	Mar. 13
" "	" "	Dec. 6	121418	R Corvi	Nov. 1	" "	" "	Oct. 23
065111	Y "	May 19	122532	T Can. Ven.	Sept. 11	152714	RU "	Feb. 14
" "	" "	Dec. 30	122803	Y Virginis	June 25	" "	" "	Dec. 30
065208	X "	May 25	123160	T Urs. Maj.	" 19	153378	S Urs. Min.	Jan. 30
" "	" "	Oct. 25	123307	R Virginis	Jan. 23	" "	" "	Dec. 10
065355	R Lynceis	Apr. 11	" "	" "	June 18	153620	U Librae	Mar. 25
070109	V Can. Min.	Oct. 6	" "	" "	Nov. 11	" "	" "	Nov. 6
070122a	R Gemin.	" 26	123459	RS Urs. Maj.	Feb. 9	154536	X Cor. Bor.	June 17
070310	R Can. Min.	May 14	" "	" "	Oct. 29	154615	R Serpents	Mar. 23
071201	RR Monoc.	" 7	123961	S "	June 29	154639	V Cor. Bor.	Dec. 6
071713	V Gemin.	Sept. 11	124204	RU Virginis	Mar. 7	154715	R Librae	Feb. 3

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1918.			1918.			1918.
154715	R Librac	Oct. 11	172809	RU Ophiuchi	Aug. 9	193509	RV Aquilae	Feb. 7
155018	RR Librac	Sept. 23	175111	RT "	July 2	"	"	Sept. 15
155229	Z Cor. Bor.	Apr. 21	175458	T Draconis	Feb. 1	194048	RT Cygni	June 14
"	" " "	Dec. 26	175519	RY Herculis	May 31	"	"	Dec. 23
155823	RZ Scorpil	May 26	175654	V Draconis	Feb. 8	194348	TU "	Apr. 21
"	" " "	Nov. 2	"	"	Nov. 13	"	"	Nov. 27
160021	Z "	Jan. 26	180531	T Herculis	May 2	194604	X Aquilae	Apr. 12
160118	R Herculis	Oct. 13	"	"	Oct. 15	194632	x Cygni	Apr. 9
160210	U Serpentin	Feb. 12	180565	W Draconis	Feb. 23	195202	RR Aquilae	Jan. 29
"	"	Oct. 11	"	"	Nov. 8	195849	Z Cygni	Feb. 8
160524	RX Scorpil	Aug. 4	180666	X "	Aug. 7	"	"	Oct. 27
160625	RU Herculis	No Max.	181103	RY Ophiuchi	May 27	200212	SY Aquilae	Apr. 13
161122a	R Scorpil	Mar. 24	"	"	Oct. 26	200357	S Cygni	Sept. 9
"	"	Nov. 1	181136	W Lyrae	Apr. 12	200514	R Capricorni	July 27
161122b	S "	June 1	"	"	Oct. 25	200715a	S Aquilae	May 11
"	"	Nov. 26	182224	SV Herculis	June 21	"	"	Oct. 6
161138	W Cor. Bor.	Aug. 9	182306	S Serpentin	May 17	200812	RU "	Sept. 2
161607	W Ophiuchi	Jan. 16	183149	SV Draconis	Apr. 24	200822	W Capricorni	Jan. 18
"	"	Dec. 12	183225	RZ Herculis	July 2	"	"	Aug. 14
162112	V "	Oct. 24	183308	X Ophiuchi	Aug. 12	200906	Z Aquilae	Jan. 13
162119	U Herculis	" 13	184134	RY Lyrae	Oct. 13	"	"	May 23
162319	Y Scorpil	June 21	184243	RW "	July 21	"	"	Sept. 30
162807	SS Herculis	Apr. 8	185032	RX "	Apr. 27	201008	R Delphini	July 31
"	"	July 23	185512	ST Sagittarii	Oct. 25	201130	SX Cygni	Oct. 10
"	"	Nov. 6	185634	Z Lyrae	Jan. 6	201647	U "	July 21
162815	T Ophiuchi	Mar. 17	"	"	Oct. 23	202622	RU Capricorni	Sept. 19
162816	S "	" 31	185737	RT "	Apr. 27	202817	Z Delphini	Mar. 2
"	"	Nov. 20	"	"	Dec. 31	"	"	Dec. 31
163137	W Herculis	July 12	190108	R Aquilae	Apr. 30	202954	ST Cygni	July 22
163266	R Draconis	Apr. 9	190529a	V Lyrae	Feb. 9	203611	Y Delphini	Mar. 25
"	"	Dec. 11	190818	RX Sagittarii	June 7	203816	S "	May 25
164319	RR Ophiuchi	July 19	190925	S Lyrae	Sept. 9	203847	V Cygni	Mar. 9
164715	S Herculis	Sept. 11	190933	RS "	" 14	204016	T Delphini	May 12
165030	RR Scorpil	Feb. 7	190941	RU "	Nov. 26	204104	W Aquarii	" 8
"	"	Nov. 15	190967	U Draconis	Aug. 6	204318	V Delphini	Oct. 5
165202	SS Ophiuchi	July 19	191007	W Aquilae	No Max.	204405	T Aquarii	June 29
165631	RV Herculis	June 3	191017	T Sagittarii	Feb. 25	205017	X Delphini	Jan. 1
"	"	Dec. 30	191019	R "	Jan. 20	"	"	Oct. 11
170215	R Ophiuchi	Oct. 5	"	"	Oct. 16	205923	R Vulpeculae	Mar. 10
170627	RT Herculis	Jan. 31	191319	S "	June 17	"	"	July 25
"	"	Dec. 2	191321	Z "	Mar. 25	"	"	Dec. 9
171401	Z Ophiuchi	Mar. 24	191637	U Lyrae	No Max.	210124	V Capricorni	Jan. 16
171723	RS Herculis	Feb. 23	192928	TY Cygni	Mar. 22	"	"	June 25
"	"	Sept. 29	193311	RT Aquilae	Mar. 9	"	"	Dec. 2
172809	RU Ophiuchi	Jan. 21	193449	R Cygni	Nov. 23	210129	TW Cygni	May 16

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1918.			1918.			1918.
210382	X Cephei	Dec. 12	215934	RT Pegasi	Oct. 29	230759	V Cassiop.	Apr. 28
210504	RS Aquarii	May 31	220412	T "	June 29	"	" "	Dec. 14
210516	Z Capricorni	Aug. 20	220613	Y "	May 7	231425	W Pegasi	Apr. 11
210868	T Cephei	Jan. 29	"	" "	Nov. 29	231508	S "	Mar. 25
210903	RR Aquarii	Apr. 2	220714	RS "	Apr. 4	233335	ST Androm.	" 23
"	" "	Oct. 5	221321	X Aquarii	June 9	233815	R Aquarii	Nov. 5
211614	X Pegasi	June 7	222439	S Lacertae	May 8	233956	Z Cassiop.	Dec. 14
"	" "	Dec. 26	223841	R "	" 17	235053	RR "	May 20
211615	T Capricorni	June 2	225120	S Aquarii	Feb. 16	235209	V Ceti	Feb. 5
213678	S Cephei	No Max.	"	" "	Nov. 19	235350	R Cassiop.	Mar. 23
214024	RR Pegasi	July 10	225914	RW Pegasi	May 4	235525	Z Pegasi	Sept. 18
215605	V "	Aug. 17	"	" "	Nov. 30	235855	Y Cassiop.	" 25
215934	RT "	Mar. 29	230110	R "	Jan. 14	235939	SV Androm.	Mar. 24

A second method of predicting times of maxima consists in deriving a formula representing past maxima, and computing future maxima by it. Such formulae will be found in H.A. 55, 1 and predictions by similar formulae are given each year in the Vierteljahrsschrift, and in the Companion to the Observatory. While this method must be used in comparing observations extending over many years, its results are not satisfactory for determining when a variable is likely to be bright enough for observation.

A comparison of the predicted dates in 1917 has accordingly been made with those which actually occurred. The latter were found by inspection of a plot of the great number of observations received here, annually. From 220 maxima observed in 1917, the average deviation of the prediction in H. C. 197 is ± 12.6 days, of that in the Vierteljahrsschrift, ± 35.0 days; 72 of these maxima are given in the Companion to the Observatory, and the average deviation is ± 28.6 days. These last predictions relate only to the brighter variables whose periods are generally more accurately known than in the case of the fainter variables. Assuming the form of the maximum to be parabolic, the error in magnitude will be proportional to the square of the error in time. When a predicted maximum is in error by a month its value is greatly diminished, since the variable would then often be one or two magnitudes fainter than when at maximum. The number of differences exceeding 30 days in the three cases are 18, 89, and 24, respectively. The corresponding percentages are 8, 41, and 33.

EDWARD C. PICKERING.

NOVEMBER 30, 1917.

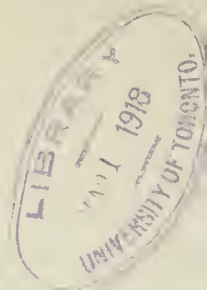
HARVARD COLLEGE OBSERVATORY.

CIRCULAR 203.

ASTEROIDS BRIGHT IN 1918.

OBSERVERS of the asteroids are dependent on the excellent ephemerides which for many years have been published by the Rechen-Institut. Abstracts of these for the years 1916 and 1917 will be found in H. C. 189 and 199. A similar abstract for 1918 is given in Table I. The form is the same as in the preceding circulars. The objects selected are those which attain the magnitude 10.0, and brighter, and Urania (30), Hecuba (108), Sirona (116), and Celuta (186), which appear to be variable. The first five columns of Table I give the number of the asteroid, its name, the date of opposition, the magnitude at that time, and the magnitude at mean opposition. The sixth column is found by subtracting the fifth column from the fourth. Negative signs predominate and indicate that the asteroid is brighter than usual, and that conditions are therefore favorable for its observation. The first and last dates given in the ephemeris, and the corresponding right ascension and declination, are contained in the next six columns. The principal use of this table will be for observers who find a moving object on their photographs. The positions given will generally indicate whether the object is known. If bright, and not given in Table I, repeated photographs should be taken. A notification should be sent at once to this Observatory so that it may be confirmed and observed elsewhere.

Any moving object is likely to be of interest, if when near opposition its right ascension does not diminish daily by much more or less than a minute. An asteroid near the Poles of the Ecliptic, R. A. = $18^h 00^m$, Dec. = $+67^\circ$ and R. A. = $6^h 00^m$, Dec. = -67° , should be followed, since it may be very near the Earth, or its orbit may have a large inclination.



CIRCULAR 203.

TABLE I.
ASTEROIDS BRIGHT IN 1918.

No.	Name.	Opp. 1918.	m	m ₀	Diff.	Date.	R. A.	Dec.	Date.	R. A.	Dec.
							<i>h. m.</i>	<i>° '</i>		<i>h. m.</i>	<i>° '</i>
11	Parthenope	Jan. 10	9.7	9.3	+0.4	Jan. 2	7 36.1	+19 27	Feb. 11	7 0.2	+21 45
79	Eurynome	" 14	10.0	10.5	-0.5	" 2	7 53.4	+12 35	" 11	7 18.3	+14 38
511	Davida	" 17	8.6	9.6	-1.0	" 2	8 7.6	+22 4	" 11	7 35.9	+27 20
22	Kalliope	" 29	9.6	9.8	-0.2	" 18	8 56.1	+35 43	" 27	8 21.2	+37 41
15	Eunomia	Feb. 6	8.8	8.6	+0.2	" 26	9 32.0	+ 7 0	Mar. 7	8 56.0	+ 7 53
30	Urania	" 15	10.2	9.9	+0.3	Feb. 3	10 7.2	+10 37	" 15	9 31.1	+13 15
78	Diana	" 21	9.4	10.6	-1.2	" 11	10 27.7	+11 10	" 23	9 53.4	+10 30
139	Juewa	" 21	9.9	10.9	-1.0	" 11	10 29.0	+21 15	" 23	9 53.6	+20 8
13	Egeria	" 24	9.4	9.7	-0.3	" 11	10 42.8	+37 42	" 23	10 3.2	+36 43
64	Angelina	Mar. 5	9.9	10.5	-0.6	" 19	11 14.7	+3 39	" 31	10 44.0	+ 6 32
52	Europa	" 6	9.9	10.3	-0.4	" 19	11 18.1	+10 44	" 31	10 51.2	+14 36
385	Ilnatar	" 8	9.5	10.3	-0.8	" 27	11 22.7	+ 4 16	Apr. 8	10 47.4	+ 3 43
6	Hebe	Apr. 8	9.6	8.5	+1.1	Mar. 23	13 19.5	+10 29	May 2	12 47.9	+14 27
186	Celuta	" 10	11.9	11.4	+0.5	" 31	13 27.7	-10 51	" 10	12 46.8	-10 12
9	Metis	" 20	9.4	8.9	+0.5	Apr. 8	13 58.4	- 5 28	" 18	13 34.2	- 4 52
124	Alkeste	" 24	9.9	10.3	-0.4	" 8	14 19.4	-12 6	" 18	13 48.8	- 8 34
26	Proserpina	May 3	10.0	10.5	-0.5	" 24	14 50.3	-15 40	June 3	14 18.8	-14 21
20	Massalia	" 12	9.6	9.2	+0.4	May 2	15 27.3	-18 24	" 11	14 52.9	-15 59
532	Herculina	" 13	9.0	9.8	-0.8	" 2	15 28.0	+ 7 0	" 11	14 57.3	+ 4 11
2	Pallas	June 7	8.8	8.0	+0.8	" 26	17 9.4	+25 19	July 5	16 38.6	+24 17
8	Flora	" 10	9.4	8.9	+0.5	" 26	17 30.1	-17 34	" 5	16 48.5	-18 15
18	Melpomene	" 13	9.5	9.3	+0.2	June 3	17 38.3	- 7 9	" 13	17 0.5	- 8 22
1	Ceres	" 24	7.6	7.4	+0.2	" 11	18 23.9	-25 57	" 21	17 48.2	-28 1
40	Harmonia	" 24	9.1	9.2	-0.1	" 11	18 26.7	-22 42	" 21	17 47.1	-24 16
14	Irene	July 12	9.8	9.7	+0.1	" 27	19 39.2	-26 17	Aug. 6	19 1.9	-29 8
194	Prokne	" 20	9.0	10.5	-1.5	July 5	20 7.2	+ 5 32	" 14	19 42.4	- 2 46
129	Antigone	Aug. 1	9.5	10.3	-0.8	" 21	20 53.4	-13 14	" 30	20 25.9	-18 37
387	Aquitania	" 23	8.5	9.8	-1.3	Aug. 14	22 15.3	-21 12	Sept. 23	21 53.5	-28 8
198	Ampella	" 26	9.6	11.1	-1.5	" 14	22 30.7	+ 8 36	" 23	22 1.3	+ 7 18
173	Ino	Sept. 17	9.8	11.0	-1.2	Sept. 7	23 46.6	-11 18	Oct. 17	23 26.3	-17 48
455	Bruchsalia	Oct. 7	9.6	11.6	-2.0	" 23	1 3.7	-19 24	Nov. 2	0 34.7	-16 10
192	Nausikaa	" 8	7.6	9.3	-1.7	" 23	1 6.5	+14 3	" 2	0 33.5	+14 14
39	Laetitia	" 8	8.8	9.5	-0.7	" 23	1 3.3	- 2 47	" 2	0 37.6	- 7 31
10	Hygiea	" 11	10.0	9.5	+0.5	Oct. 1	1 13.8	+13 35	" 10	0 47.2	+10 34
68	Leto	" 19	9.5	10.5	-1.0	" 9	1 43.3	+ 4 48	" 18	1 12.1	+ 4 51
108	Hecuba	Nov. 1	11.9	11.7	+0.2	" 17	2 37.2	+19 55	" 26	2 7.2	+17 51
12	Victoria	" 3	9.6	9.7	-0.1	" 25	2 44.4	+20 20	Dec. 4	2 11.4	+14 41
116	Sirona	Dec. 13	10.4	10.7	-0.3	Dec. 4	5 32.5	+24 44	" 44	4 56.7	+24 52
415	Palatia	" 24	9.7	11.6	-1.9	" 12	6 22.3	+13 8	" 52	5 52.9	+17 18
182	Elsa	" 30	10.0	11.0	-1.0	" 20	6 46.7	+22 9	" 60	6 12.1	+23 33

EDWARD C. PICKERING.

JANUARY 9, 1918.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 204.

NOVA PERSEI, No. 2. 032443.

THE recent observation of Belopolsky that Nova Persei, No. 2, 032443, underwent rapid changes in light during last August, will probably lead to many observations of this object. These observations will have little value unless means are provided for reducing them all to the same scale. It is hoped that astronomers will either use the comparison stars given below, or at least measure some of them, both brighter and fainter than the Nova, so that their measures can be reduced to the photometric scale.

In H.A. 48, No. 2, Mr. Leon Campbell collected the observations of this object in 1901 and 1902, and has brought the material up to the present time in the following tables. Seventy-five comparison stars were used in H.A. 48, of the ninth magnitude, and brighter. A continuation of this list is given in Table I. The successive columns give a number for reference, the

TABLE I.
COMPARISON STARS.

No.	Hagen.	R.A. 1900.			Dec. 1900.	Ptm.	Ptg.	No.	Hagen.	R.A. 1900.			Dec. 1900.	Ptm.	Ptg.
N	..	<i>h. m. s.</i>			<i>° ' "</i>			86	66	<i>h. m. s.</i>			<i>° ' "</i>		
76	24	3 24 24			+43 33.7	..	..	87	68	3 24 57			+43 29.7	13.26	13.33
77	31	25 58			53.8	9.40	..	88	74	24 57			35.2	13.40	13.26
78	32	26 21			49.4	9.82	9.63	89	77	25 6			38.6	13.57	13.54
79	34	25 7			42.4	9.91	10.53	90	80	24 36			34.9	13.85	13.64
80	42	23 19			37.0	10.23	11.30	91	80	24 55			31.4	..	13.80
81	46	24 59			33.9	11.03	10.91	92	..	24 18			32.0	..	14.04
82	49	23 2			40.0	11.88	11.96	93	..	24 57			33.0	..	14.57
83	50	23 59			32.3	12.29	12.49	94	..	24 36			34.2	..	14.76
84	56	23 1			42.9	12.37	11.74	95	..	24 8			28.5	..	15.00
85	65	24 4			36.2	12.75	12.82		..	24 33			35.2	..	15.50
		24 45			35.4	13.23	13.61								

number in Hagen's Second Catalogue of stars near Nova Persei, the right ascension for 1900, the declination for 1900, the photometric magnitude, and

the photographic magnitude on the international scale. The photometric magnitude of the brighter stars is derived from the estimated brightness, in grades, by Hagen, reduced graphically by the measures of Wendell given in Table I of H.A. 66. The order is that of photometric brightness. The photographic magnitudes are added for convenience of reference. They were derived by Miss Leavitt from a discussion which will be published later.

The individual observations are contained in Table II. The year, month, and day are given in the first column, the Julian Day in the second, and the observed magnitude in the third, when not on the photometric scale. The magnitude reduced to the photometric scale is given in the fourth column. The name of the observer is given in the fifth column and the reference, in the sixth.

TABLE II.
INDIVIDUAL OBSERVATIONS.

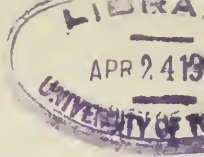
Date.	J.D.	Obs.	Ptm.	Observer.	Reference.	Date.	J.D.	Obs.	Ptm.	Observer.	Reference.
<i>y. m. d.</i>						<i>y. m. d.</i>					
02 6 25	15926	8.83	8.9	Nijland	A.N. 168,133	03 3 1	16175	9.6	10.3	Kohl	A.S.P. 16, 26
6 27	15928	8.76	8.8	"	" " "	3 2	16176	..	10.2	Campbell	H.C.O.
7 6	15937	8.89	9.0	"	" " "	3 11	16185	..	10.2	"	"
7 14	15944	8.97	9.2	"	" " "	3 20	16194	..	10.3	"	"
7 23	15954	8.83	8.9	"	" " "	3 22	16196	9.6	10.3	Kohl	A.S.P. 16, 26
9 6	15999	9.05	9.3	"	" " "	3 23	16197	9.8	10.6	Luther	A.N. 161,409
9 8	16001	9.2	9.5	"	" " "	4 2	16207	9.6	10.3	Kohl	A.S.P. 16, 26
9 23	16016	9.2	9.5	"	" " "	4 14	16219	10.0	10.9	"	" " "
9 23	16016	9.57	10.1	"	" " "	4 22	16227	10.0	10.9	"	" " "
9 27	16020	9.60	10.1	"	" " "	4 28	16233	..	10.3	Campbell	H.C.O.
9 28	16021	9.69	10.2	"	" " "	7 19	16315	9.9	10.6	Nijland	A.N. 168,133
10 23	16046	..	9.9	Campbell	H.C.O.	8 15	16342	10.25	11.2	"	" " "
10 28	16051	..	9.9	"	"	8 16	16343	10.1	11.0	Kohl	A.S.P. 16, 26
10 30	16053	9.78	10.4	Nijland	A.N. 168,133	8 21	16348	10.2	11.2	"	" " "
11 17	16071	9.55	10.1	"	" " "	8 22	16349	10.0	10.9	"	" " "
03 1 1	16116	9.2	9.7	Kohl	A.S.P. 16, 26	8 25	16352	10.05	10.9	Nijland	A.N. 168,133
1 4	16119	9.2	9.7	"	" " "	9 1	16359	10.31	11.3	"	" " "
1 7	16122	9.44	9.9	Nijland	A.N. 168,133	9 2	16360	..	10.7	Campbell	H.C.O.
1 8	16123	9.2	9.7	Kohl	A.S.P. 16, 26	9 12	16370	10.2	11.2	Kohl	A.S.P. 16, 26
1 17	16132	..	10.2	Campbell	H.C.O.	9 12	16370	..	10.7	Campbell	H.C.O.
1 19	16134	9.4	10.0	Kohl	A.S.P. 16, 26	9 17	16375	9.94	10.7	Nijland	A.N. 168,133
1 31	16146	..	10.1	Campbell	H.C.O.	9 19	16377	10.0	10.9	Kohl	A.S.P. 16, 26
2 1	16147	9.6	10.3	Kohl	A.S.P. 16, 26	9 21	16379	..	10.7	Campbell	H.C.O.
2 10	16156	..	10.2	Campbell	H.C.O.	9 23	16381	10.0	10.9	Kohl	A.S.P. 16, 26
2 15	16161	9.6	10.3	Kohl	A.S.P. 16, 26	9 24	16382	..	10.5	Campbell	H.C.O.
2 16	16112	9.65	10.2	Nijland	A.N. 168,133	9 25	16383	10.0	10.9	Kohl	A.S.P. 16, 26
2 18	16164	..	10.3	Campbell	H.C.O.	10 20	16408	10.0	10.9	"	" " "
2 20	16166	..	10.2	"	"	10 26	16414	..	10.8	Campbell	H.C.O.
2 23	16169	..	10.3	"	"	11 20	16439	..	10.9	"	"
2 25	16171	9.6	10.3	Kohl	A.S.P. 16, 26	04 1 19	16499	10.1	11.0	Kohl	A.S.P. 17, 18

Date.	J.D.	Obs.	Ptm.	Observer.	Reference.	Date.	J.D.	Obs.	Ptm.	Observer.	Reference.
<i>y. m. d.</i>						<i>y. m. d.</i>					
04 2 15	16526	10.2	11.1	Kohl	A.S.P. 17, 18	07 1 7	17583	10.55	11.6	Nijland	A.N. 180,118
2 20	16531	..	11.3	Campbell	H.C.O.	2 6	17613	10.36	11.4	"	" " "
2 22	16533	10.1	11.0	Kohl	A.S.P. 17, 18	2 11	17618	10.8	12.0	Markwick	B.A.A. 18,283
3 2	16542	10.1	11.0	"	" " "	3 10	17645	10.7	11.9	"	" " "
3 12	16552	10.0	10.9	"	" " "	3 14	17649	10.55	11.6	Nijland	A.N. 180,118
4 2	16573	9.9	10.7	"	" " "	3 25	17660	..	11.8	Campbell	H.C.O.
4 5	16576	..	11.3	Campbell	H.C.O.	4 1	17667	10.2	11.2	Markwick	B.A.A. 18,283
4 12	16583	10.0	10.9	Kohl	A.S.P. 17, 18	4 14	17680	10.78	12.0	Nijland	A.N. 180,118
7 19	16681	10.55	11.6	Nijland	A.N. 180,118	7 14	17771	10.53	11.6	"	" " "
8 13	16706	10.3	11.3	Kohl	A.S.P. 17, 18	8 24	17812	10.70	11.9	"	" " "
8 15	16708	..	11.8	Campbell	H.C.O.	9 8	17827	10.57	11.7	"	" " "
9 4	16728	10.4	11.4	Kohl	A.S.P. 17, 18	9 9	17828	10.3	11.3	Markwick	B.A.A. 18,283
9 10	16734	10.4	11.4	"	" " "	10 3	17852	10.55	11.7	"	" " "
9 30	16754	..	11.8	Campbell	H.C.O.	10 10	17859	10.43	11.5	Nijland	A.N. 180,118
10 3	16757	10.7	11.8	Nijland	A.N. 180,118	10 10	17859	..	11.8	Campbell	H.C.O.
10 5	16759	11.0	12.3	Kohl	A.S.P. 17, 18	11 8	17888	10.53	11.6	Nijland	A.N. 180,118
10 29	16783	..	11.0	Cannon	H.C.O.	11 15	17895	10.6	11.7	Brook	B.A.A. 18,283
11 6	16791	10.1	11.0	Kohl	A.S.P. 17, 18	12 6	17916	10.24	11.2	Markwick	" " "
11 12	16797	..	11.4	Cannon	H.C.O.	12 11	17921	10.48	11.6	Nijland	A.N. 180,118
12 28	16843	10.4	11.4	Kohl	A.S.P. 17, 18	08 1 3	17944	..	11.9	Campbell	H.C.O.
12 30	16845	10.55	11.6	Nijland	A.N. 180,118	1 10	17951	10.50	11.6	Nijland	A.N. 180,118
05 1 12	16858	10.74	11.9	"	" " "	2 3	17975	10.75	12.0	Markwick	B.A.A. 19,336
1 31	16877	..	11.5	Cannon	H.C.O.	2 5	17977	10.82	12.0	Nijland	A.N. 180,118
2 2	16879	10.57	11.8	Nijland	A.N. 180,118	2 23	17995	10.70	11.9	"	" " "
3 9	16914	10.3	11.4	Brook	B.A.A. 17,120	2 24	17996	11.0	12.3	Markwick	B.A.A. 19,336
3 12	16917	10.50	11.7	Nijland	A.N. 180,118	2 24	17996	..	12.0	Campbell	H.C.O.
3 27	16932	..	12.0	Cannon	H.C.O.	3 5	18006	..	11.9	"	"
4 3	16939	10.80	12.0	Nijland	A.N. 180,118	3 9	18010	10.60	11.6	Nijland	A.N. 180,118
7 7	17034	10.68	11.9	"	" " "	3 23	18024	10.61	11.7	"	" " "
7 31	17058	10.9	12.2	Brook	B.A.A. 17,120	4 5	18037	10.61	11.7	Nijland	" " "
8 5	17063	10.78	12.0	Nijland	A.N. 180,118	8 3	18157	11.2	12.6	Brook	B.A.A. 19,336
9 18	17107	10.50	11.6	Nijland	A.N. 180,118	8 30	18184	11.2	12.6	"	" " "
9 23	17112	..	11.8	Campbell	H.C.O.	10 22	18237	11.1	12.5	Markwick	" " "
10 19	17138	10.40	11.6	Nijland	A.N. 180,118	10 30	18245	..	12.1	Campbell	H.C.O.
11 16	17166	10.50	11.6	"	" " "	12 21	18297	..	12.1	"	"
12 9	17189	10.51	11.7	"	" " "	09 2 26	18364	..	12.5	"	"
06 1 17	17228	..	11.6	Campbell	H.C.O.	3 29	18395	..	12.6	"	"
1 17	17228	10.27	11.3	Nijland	A.N. 180,118	10 5	18585	..	12.6	"	"
2 9	17251	10.48	11.6	"	" " "	11 5	18616	..	12.1	"	"
3 1	17271	..	11.4	Campbell	H.C.O.	11 30	18641	..	11.8	"	"
3 14	17284	10.50	11.6	Nijland	A.N. 180,118	10 2 14	18717	..	11.7	"	"
4 3	17304	10.53	11.6	"	" " "	3 9	18740	..	11.7	"	"
4 16	17317	10.70	11.9	"	" " "	9 29	18944	..	12.4	"	"
7 13	17405	10.50	11.6	"	" " "	12 9 8	19654	12.1	13.3	Barnard	A.N. 198,123
8 15	17438	10.61	11.7	"	" " "	10 15	19691	12.0	13.2	"	" " "
9 22	17476	10.56	11.6	"	" " "	10 26	19702	12.4	13.7	"	" " "
10 9	17493	10.50	11.6	"	" " "	13 2 12	19811	10.8	11.7	Bohlin	A.N. 197,369
10 12	17496	..	11.4	Campbell	H.C.O.	14 2 14	20178	12.4	13.7	Barnard	A.N. 198,123
11 10	17525	10.70	11.9	Nijland	A.N. 180,118	15 8 31	20741	12.4	12.6	Maanen	H.B. 645
12 7	17552	10.10	11.9	"	" " "	9 2	20743	12.4	12.6	"	" "

Date.	J.D.	Obs.	Ptm.	Observer.	Reference.	Date.	J.D.	Obs.	Ptm.	Observer.	Reference.
<i>y. m. d.</i>						<i>y. m. d.</i>					
15 9 30	20771	12.5	12.8	Maanen	H.B. 645	17 2 20	21280	12.6	13.9	Barnard	H.B. 644
10 6	20777	..	12.3	Campbell	H.C.O.	3 19	21307	..	14.5	Campbell	H.C.O.
16 1 5	20868	12.4	13.7	Barnard	H.B. 644	8 16	21457	13	..	Belopolsky	H.B. 643
1 11	20874	12.6	13.0	Maanen	H.B. 645	8 18	21459	12.9	14.3	Barnard	H.B. 644
1 12	20875	12.7	13.2	"	" "	8 28	21469	11.5	..	Belopolsky	H.B. 643
2 29	20923	..	11.8	Campbell	H.C.O.	8 29	21470	11.9	13.0	Barnard	H.B. 644
12 9	21207	13.8	15.0	Barnard	H.B. 644	8 30	21471	11.6	12.6	"	" "
12 16	21214	13.0	14.4	"	" "	9 5	21477	12.1	13.3	"	" "
12 18	21216	13.8	15.0	Maanen	H.B. 645	9 14	21486	12.8	13.3	Maanen	H.B. 645
12 21	21219	13.1	14.6	Barnard	H.B. 644	9 25	21497	..	13.6	Campbell	H.C.O.
12 27	21225	12.9	14.3	"	" "	10 13	21515	..	13.6	"	"
12 30	21228	13.3	14.8	"	" "	10 22	21524	..	13.6	"	"
17 1 23	21251	12.0	13.2	"	" "	12 7	21570	..	14.5	"	"
2 10	21270	12.7	14.0	"	" "						

EDWARD C. PICKERING.

DECEMBER 18, 1917.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 205.

THE DISTANCE OF THE GREAT NEBULA IN ORION.

IN H.A. 32 a statistical investigation was made of the brightness of all the stars in the immediate vicinity of this body. The region covered extends in general from R. A. = $5^h 27^m 20^s$ to $5^h 32^m 50^s$, and from Dec. = $-4^\circ 27'$ to $-6^\circ 16'$. It includes therefore the whole region of the so-called "sword handle" and the naked eye stars ϵ , θ , and ι . This same region had previously been studied by G. P. Bond, H.A. 5, and visual estimates made of the brightness of all the stars he could see in it. Judging by the comparatively large number he recorded as of magnitude 14.8, about 12 per cent of the whole, it is probable that he regarded these as the faintest stars he could clearly see. Since he observed with the 15-inch Refractor this is doubtless nearly correct. There were 19 stars, 3 per cent, which he entered as ranging from 14.9 to 16.4, and these he probably only glimpsed. Several of them were involved in the nebula. In what follows we have assumed that these should all have been recorded as 15.0. Very likely some of them were really brighter. The next grade of stars brighter than 14.8 he calls 13.9, and the next 13.1. These he might properly have called 14 and 13, but no correction to his figures has been deemed necessary. He also records a few straggling intermediate magnitudes, which have been left unchanged. His estimates of the naked eye stars were quite erroneous, varying from 1.4 to 2.9 magnitudes too faint, but errors of this sort were not uncommon among astronomers before the days of exact photometric measurements, and will affect our results but little, since these stars are few in number. His other estimates appear to have been fairly good.

The writer's investigation was based on photography, and is fully described in the above mentioned article. In Table VII there shown, the photographic magnitudes were standardized by the results of the meridian photometer. In Table I below, they are corrected by the Revised Harvard Photometry, the successive columns giving the numbers in the original table, the corresponding

numbers in the H. R., the photometric and photographic magnitudes, their difference, and the type of spectrum. Omitting number 4 which is of type F, we see that the residuals balance, and that therefore the photographic magnitudes based on these standards should coincide with the visual magnitudes

TABLE I.

STARS OF STANDARD MAGNITUDE.

No.	H.R.	Photom.	Photog.	Diff.	Type.
1	1899	2.9	2.9	0.0	Oe5
2	1892	4.6	4.8	-0.2	B3
3	1887	4.7	5.2	-0.5	B1
4	1901	5.3	6.0	-0.7	F0
5	1898	6.3	6.0	+0.3	B5
6	1891	6.3	6.1	+0.2	B0
7	1923	6.3	6.2	+0.1	B1

for all stars of types Oe5 to B5. For redder stars the photographic magnitudes would be fainter than Bond's visual ones.

In H.A. 32 Table VIII is given a comparison of the photometric and photographic magnitudes of about 600 stars, but in Table XII it is shown that Bond's scale of magnitudes varied somewhat in different regions. In the bright nebulous region, and in the vicinity of the bright stars clustering about ϵ and ι his magnitudes for the fainter stars average about 0.4 too faint. Making this correction, if we

count the stars in the nebulous region in Table VIII for each photographic magnitude, where the photographic magnitude is brighter than the visual, we shall obtain a collection of stars which are certainly blue, although it probably does not include all of the stars of Type B. These results are given in the first and second columns of Table II. The third column gives the count of the remaining stars in the nebulous region, which are redder than the others and which we have classified as white. This nebulous region includes the stars of Table VIII which Bond has numbered from 471 to 800 inclusive. It consists of a meridional band extending from the top to the bottom of the chart H.A. 32 Plate 4, and lying between R. A. = $5^h 29^m.8$ and $5^h 30^m.8$. Its area is 0.452 square degrees, that of the whole region considered being 2.487. Their ratio is 0.182. A count was next made of the stars in the remaining area on either side of the nebula, the blue stars being recorded in the fourth column and the white ones in the fifth. The total numbers of blue and white stars are recorded in the sixth and seventh columns. The eighth and ninth give the corrected numbers of these stars in the nebulous region. These results are obtained by subtracting 0.182 times the number of stars given in the sixth and seventh columns from the numbers given in the second and third. That is, we assume that the same density of stars are superposed over the nebulous region that we find in the area outside of it. Doubtless many of these outside stars are really connected with the nebula, but the so-called corrected

results refer simply to the very innermost stars of all associated with it. The tenth and eleventh columns give the products obtained by multiplying the numbers in the first column by those given in the eighth and ninth. The next to the last horizontal line gives the total number of stars or weighted magnitudes in each column, and the last line, the number of stars per square degree for columns two to five, and the mean of the magnitudes for the last two columns. We notice that outside of the nebulous region the density of the blue stars is but one-fifth that within it. The white stars also are fewer in number, their density being but two-fifths as great. Their diminution in density shows clearly that a considerable proportion of them also belong to the nebula.

TABLE II.
DISTRIBUTION OF STARS OF DIFFERENT TYPES.

Magn.	Nebula.		Surroundings.		Totals.		Inner.		Weights.	
	Blue.	White.	Blue.	White.	Blue.	White.	Blue.	White.	Blue.	White.
3	1	0	0	0	1	0	1	0	3	0
4	0	0	0	0	0	0	0	0	0	0
5	2	0	0	0	2	0	2	0	10	0
6	5	1	2	0	7	1	4	1	24	6
7	6	2	7	0	13	2	4	2	28	14
8	12	1	3	0	15	1	9	1	72	8
9	10	3	20	1	30	4	5	2	45	18
10	7	14	29	15	36	29	0	9	0	90
11	16	14	16	28	32	42	10	6	110	66
12	19	19	5	39	24	58	15	8	180	96
13	25	22	25	31	50	53	16	12	208	156
14	8	19	16	71	24	90	4	3	56	42
15	0	18	0	84	0	102	0	-1	0	-15
16	0	3	0	8	0	11	0	1	0	16
Totals	111	116	123	277	234	393	70	44	736	497
Density	245	257	49	111	..	..	..	..	10.5	11.3

These results are plotted in Figure I where the abscissas give the photographic magnitudes and the ordinates the number of stars. The heavy lines represent the blue stars and the light ones those that are white. The lower lines in each case refer to the nebulous region and the upper ones to the total number of stars. On examining the curves we notice in the first place that in both areas the blue stars come to an end on reaching the fifteenth magnitude. This, however, necessarily follows our method of reduction, since

we concluded that the faintest stars recorded visually by Bond were of that degree of brightness, and therefore any that were brighter photographically would necessarily be entered as of the fourteenth magnitude. Nevertheless we notice in spite of this small addition to their numbers, and in spite of

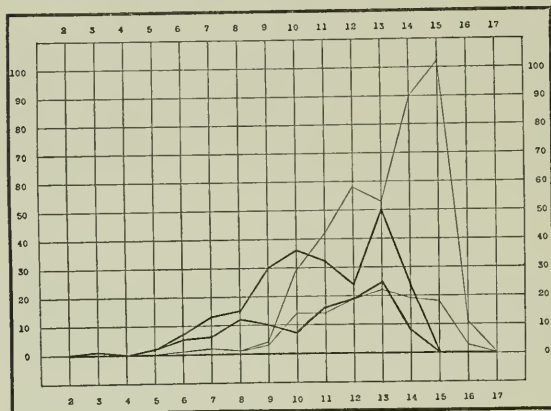


FIG. 1.

the large number of stars recorded by Bond as of magnitude 14.8, that in both curves the blue stars of the fourteenth magnitude are far fewer in number than those of the thirteenth, while outside of the nebulous region there is, on the other hand, a very marked increase among the white stars, not only of the fourteenth but even of the fifteenth magnitude, over those of the thirteenth. It appears therefore that we really have come to the end of the blue stars, and that their numbers will not be increased by more powerful instruments, or by longer exposures.

Dr. Charlier in his recent memoir on the stars of type B states that there are none fainter than the 8.5 magnitude. This appears to be an error. We next notice that up to the fifteenth magnitude the white stars increase in numbers almost along a straight line, from the vicinity of the eighth magnitude. The drop after the fifteenth is undoubtedly due to lack of instrumental power, and there is no evidence of the stars suddenly falling off in numbers with diminishing light in this portion of the heavens. Recalling that the nebulous region is but about one-fifth of the total area considered, we find that among the fourteenth and fifteenth magnitude white stars it contains about one-fifth of the total number of stars. For magnitudes brighter than the fourteenth, however, the proportion is greatly increased, and at the tenth magnitude one-half of the white stars are in the nebulous region. From this we conclude that there are very few of these stars in the nebula itself of the fourteenth magnitude, and that there is no evidence that it contains stars of any type fainter than the fifteenth. These results are shown numerically in

the eighth and ninth columns of Table II. Both types of stars are numerous up to the thirteenth magnitude, but diminish rapidly after that.

We now, therefore, have a record of all the stars that it contains, and any fainter stars recorded upon our plates must be considered as being merely superposed upon it. Since the maximum number of stars both white and blue, within the nebula, are found to be of the thirteenth magnitude, and since there are none at all of the fifteenth, this very sudden drop would seem to imply that practically all of the stars are of one type, namely B. If there are any stars of types A and F, there are clearly no dwarfs among them, or the magnitudes would have faded out more gradually. We notice by the figure that up to about the tenth magnitude the blue stars outnumber the white ones in both regions, but that after the thirteenth magnitude the white ones far outnumber the blue. The sharp falling off in the number of blue stars in the vicinity of the twelfth magnitude in the region outside of the nebula, is conspicuous both in the region preceding and in that following it, and may be real, but is very possibly due to some irregularity in the scale of visual magnitudes adopted.

Since we are looking at the nebula very nearly along the axis of the great spiral, H.A. 32, Plate III, Figure 4, all of the stars associated with it must be at approximately the same distance from us. We should not, for instance, expect a greater range of distance than, let us say, twenty-five per cent from the mean. The brightness of any star could not, therefore, be affected by its distance from us by more than one-half a magnitude. The bright star ι is obviously connected with the nebula, as is shown by the chart above mentioned, Plate IV, and also by the photograph, Plate III, Figure 2. It is eleven magnitudes brighter than many of the fainter B stars associated with the nebula, and the ratio of its light to theirs is therefore 25,000 times as great. It appears, therefore, that there is as great a range of absolute brightness among the B stars in this region of the heavens as there is in any other type, or perhaps even greater. It would seem however that ι must be a giant among giants, since the fourteenth magnitude B stars are by no means dwarfs. Perhaps we may properly describe these stars as consisting of many giants and a few supergiants. Both of the curves indicate that there is no defined upper limit to the size of the B stars, although the lower limit as above indicated is so clearly marked. Coming now to the question of the distance of the nebula, it has been shown very conclusively by Russell and others that in order for a star to reach the

color of type B, not only must it be very massive, but its intrinsic, and therefore its total light must be enormous. In his address given before the Astronomical Society of America, and published in *Popular Astronomy*, 22 1914, May and June, in Tables V and VII he gives the absolute magnitude of a star of type B2 as -1.2 and -1.4 . The value computed by his formula would be -1.1 . On the same scale the magnitude of the Sun would be $+4.8$. The magnitude falls off rapidly however, so that for a star of type A0 the absolute magnitude is reduced to $+0.5$.

In Charlier's paper above mentioned, according to Crommelin, Knowledge, 1916, 39, 218, a B star of magnitude 0.0 is computed to be distant seventy-five light years. Reducing this to the same terms given by Russell, the absolute magnitude would be -1.8 . By Russell's formula it should be -1.5 . It appears therefore that there is a little uncertainty as to the correct value of the absolute magnitude. But there is much greater uncertainty as to what position between types B and A the stars that we have called "blue stars" really occupy. This is due to the fact that the absolute values of Bond's visual magnitudes are very uncertain. The Orion stars in general belong to type B, and the so-called "blue stars" as we have seen were the very bluest of these. Of 60 stars in the constellation given in the H. R. belonging to types O and B, ninety per cent were of type B3 and bluer. It has therefore been decided that we shall not exaggerate if we classify the blue stars as of type B3, and call their absolute magnitude -1.0 . But even if it were only 0.0 our resulting distance would be reduced by only 40 per cent.

The mean magnitude of the 234 blue stars that form the subject of this investigation is 10.8, but in determining the absolute magnitude of a star of type B no such supergiants were considered by Russell and Charlier as those with which we now have to deal. But even if we eliminate all blue stars brighter than the eighth magnitude, our mean is reduced only to 11.2, so that this correction is seen to be insignificant. If we consider only the 70 innermost stars recorded in the eighth column of Table II, we find by the tenth column that their mean magnitude is 10.5, and this is the figure that we shall adopt as our mean magnitude for the Orion stars. This is just 11.5 magnitudes fainter than they would be if placed at a distance of 10 parsecs, where their parallax would be $0''.1$. This corresponds to a distance of 2000 parsecs, or 6520 light years, and gives us a parallax of $0''.00050$.

This constant at once leads to a number of interesting results. At this distance $1''$ corresponds to a distance of 0.0315 light years, $1'$ to 1.89, and 1°

to 113. Since the diameter of the great spiral nebula is 15° , this implies a diameter of 1700 light years. The mean diameter of the brilliant Huyghenian region is $200''$ or 6.3 light years, and the distance between the trapezium stars A and D (the extreme ones) is $21''.5$, or at the least 0.68 of a light year, the latter being equivalent to 63,000 times the radius of the Earth's orbit. The star ι is not the only bright star involved in the nebulosity. Both ζ and ϵ , of the second magnitude, lie on the arm of the great spiral, and β of the 0.34 magnitude is not far away, and is just ten times as bright as ι . Its distance from its small companion is $9''.5$ or at least 0.3 of a light year. It is no wonder then that no evidence of relative motion between them has been detected. The proper motion of β according to Boss is $0''.0018$. Since there is little motion in the line of sight, save that due to the solar system, and that is directed nearly away from this star, its rate of motion is approximately 16 km. per sec. Observations of Burnham led him to suspect that the companion was a visual binary in rapid rotation, but this does not seem possible considering its distance.

It was formerly universally supposed that the nebulae were condensing, but in the earlier paper, above mentioned, p. 75, it was shown that an appearance somewhat similar to the nebula was produced by photographing an explosion of flash powder. It was further shown from the proper motions given by Auwers of the 19 stars lying within the bounds of the great spiral, that 68 per cent of their total motion was directed away from the centre of the nebula, and that 82 per cent of it lay along the coils of the spiral in a receding direction. It further appeared that the nine inner stars were moving rapidly outwards, while in the case of the outer ten this motion was negligible, or even negative,—an interesting case of stellar acceleration, and the only one recorded hitherto.

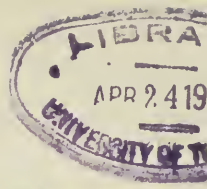
Considering now the brightness of these stars we were formerly taught to think of Sirius, which is 20 times as bright as our Sun, as a very brilliant object. Later we have learned that Antares is 3500 times as bright as our solar unit, and we know from its parallax, or lack of it, that Canopus must be at least as bright and is probably brighter than Antares. Walkey in *Knowledge* 1914, 37,288 makes its brightness 50,000 times that of our Sun. But these figures all fade into insignificance when compared to some of the Orion stars. We have already assumed, following Russell and Charlier, the average blue star to have an absolute magnitude of 5.8 greater than that of the Sun, corresponding to a brilliancy of 210 times as great. But ι of the

third apparent magnitude is seven and a half magnitudes, or 1000 times brighter than these average stars, and β is ten times as bright as ι . It is therefore 2,100,000 times the brightness of our Sun. It is possibly the brightest of all created objects. In such a furnace we can well imagine that our chemical elements might have been born, while in the case of the nebulous stars, hydrogen and nebium, perhaps concealing the spectra of the other elements, pass off like comet's tails, either to be later condensed into smaller suns, or as waste products of creation.

An examination of the Frontispiece of H.A. 32, and of Plate III, Figure 1, shows projected on the dark sky, and close to the brighter portions of the nebula, several minute nebulous clouds, but little larger than the star images themselves, and quite separated from the main mass though on a faintly luminous background. Similar objects projected on the great nebula are shown in the drawing, Plate IV. They are of all degrees of brightness, and it is possible represent the pre-stellar state of matter. A somewhat later state is shown by the nebulous stars, such as that one represented in Plate II, Fig. 7.

WILLIAM H. PICKERING.

DECEMBER 19, 1917.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 206.

THE DISTANCE OF THE PLEIADES.

THE method of determining the stellar parallax suggested by Russell in Popular Astronomy, 1914, 22, 291 is particularly well adapted to measuring the distance of clusters. He gives a formula for determining the absolute magnitude of a star, dependent on the type of its spectrum. This formula expressed slightly differently reads $M = 0.6 + 2.1 (t - 2)$, where M is the absolute magnitude, and t is the type, counting B as 1, A as 2, F as 3, G as 4, and K as 5. He states that the residuals from this formula for the mean magnitudes of the observed stars of the different classes average ± 0.29 . This corresponds to a mean error in the distance of the star of 0.14, or only one-seventh.

In the H. R. are given the brightness and types of the thirteen brighter stars in the Pleiades. Two of them however have peculiar spectra, one of them giving bright lines. They are therefore ruled out, leaving eleven, of which six belong to type B5, and five to type B8. In Popular Astronomy, 1918, 26, 9 is given a paper by Trümpler on the constitution of the Pleiades. He uses the Potsdam magnitudes, but they agree so closely with the Harvard values that the formula can be applied without error. He states that the group contains fifteen stars between magnitudes 6.5 and 7.5 whose mean type of spectrum is A0, twenty-seven stars between 7.5 and 8.5 whose mean type is A1, and twenty-nine stars between 8.5 and 9.5 whose mean type is A9.

These results are entered in Table I, where the first column gives the type, the second the number of stars considered, the third their mean apparent magnitude, the fourth their absolute magnitude computed by the formula, and the fifth the difference between the two. The results in this column should all be identical if the facts are as stated, and the formula accurately represents the facts. We found in our paper on the Distance of the Orion Nebula, Circular 205, that scattered among the giant stars of type B were a

few supergiants. We may assume that the same holds true in the case of the Pleiades, although their brilliancy is by no means as marked as in the case of Orion. Five of the six brightest stars in the cluster belong to type B5. Omitting therefore this type, and taking the mean of the other numbers, we find 6.46 as the mean difference of the magnitudes. The sixth column gives the deviations from this value, and shows an average deviation of ± 0.39 , a result slightly larger than that given by Russell as derived from

TABLE I.
THE PLEIADES.

Type.	No.	App.	Abs.	Diff.	Dev.	Parsecs.	Years.	Ratios.
B5	6	4.14	-0.45	(4.59)	..	(83)	(270)	..
B8	5	5.91	+0.18	5.73	-0.73	140	456	0.70
A0	15	7.00	+0.60	6.40	-0.06	191	621	0.95
A1	27	8.00	+0.81	7.19	+0.73	274	893	1.36
A9	29	9.00	+2.49	6.51	+0.05	200	653	1.00
Mean				6.46	± 0.39	201	656	± 0.18

all the observed stars. The difference of magnitude multiplied by 0.2 gives us the logarithm of the distance of the group stated in units of 10 parsecs, or dekaparsecs, dps, if we may suggest the name. The various distances in parsecs and in light years are indicated in the seventh and eighth columns, their mean values, omitting the first type, being 201 and 656, respectively. The last column gives the ratios to the mean distance, derived from the four different types of stars, the average deviation being ± 0.18 . The reciprocal of 201 gives us the mean parallax of the group $0''.0050 \pm 0''.0008$. The Pleiades are consequently just five times as remote as the Hyades, and as seen from the Hyades would appear much as they do to us.

The apparent distance between the two farthest apart of the six bright stars is 63'. The real distance between them is therefore at least 12.0 light years. The diameter of the whole group according to Trümpler is about 6°, or seventy light years. The apparent magnitude of Alcyone, the central star of the group, is 2.96, and subtracting the correction for distance 6.46 gives us an absolute magnitude of -3.50, which is 8.3 magnitudes, or 2100 times brighter than our Sun. The other five bright stars average 800 times as bright, and their real distances from Alcyone, assuming the latter to be

centrally located, are about the same as that from the Sun to Sirius. Since they are in reality 16 times brighter than the latter body, they would appear as seen from Aleyone of about the same brightness as Venus at its brightest does to us. The three close companions of Aleyone, however, although really much fainter, would on account of their proximity appear about equally bright.

THE DISTANCE OF COMA BERENICES.

This cluster although not conspicuous like the Pleiades, is interesting as being one of those in our immediate neighborhood. A negative of this region of the heavens was first taken with a wide angle lens of thirteen inches focus. On examination it was found that the brighter stars of the group fall off in numbers very rapidly after passing magnitude 6.5, and that the density of the fainter stars appears no greater within than without the group. The cluster lies between R. A. $12^h 10^m$ and $12^h 30^m$, and between Dec. $+23^\circ$ and $+28^\circ$, an area of about 5° on a side. Within this area twenty stars are included in the H. R., ranging in brightness from 4.78 to 6.69. Two of them are ruled out as having peculiar spectra, and three more because their proper motions are very different from those of the rest of the group. Counts in equal areas of the sky preceding and following the cluster show that two to three stars of this brightness may properly be allowed as occurring on the background in this portion of the heavens.

The remaining fifteen are entered in Table II which is arranged precisely like Table I. Twelve of these stars belong to type A, and all of them are

TABLE II.
COMA BERENICES.

Type.	No.	App.	Abs.	Diff.	Dev.	Parsecs.	Years.	Ratios.
A0	4	6.17	0.60	5.57	+0.81	130	424	1.41
A2	3	5.43	1.02	4.41	-0.35	76	248	0.82
A3	3	6.19	1.23	4.96	+0.20	98	320	1.06
A5	2	5.73	1.65	4.08	-0.68	65	213	0.71
F0	1	6.30	2.70	(3.60)	..	..	..	..
F5	1	5.49	3.75	(1.74)	..	..	..	..
G5	1	5.06	5.85	(-0.79)	..	..	..	..
Mean				4.76	± 0.51	92	301	± 0.24

probably included in the cluster. The remaining three belonging to types F and G may be nearer objects superposed upon it, or they may be giant stars within it, like Aldebaran in the Taurus cluster and Antares in the moving cluster in Scorpius. In any case the formula would not apply to them, since it is adapted only to dwarf stars. It seems likely that these three yellow stars really belong to the cluster, but the suggestion is made that since the last one, H. R. 4667, is brighter than it should be even if as near as 10 parsecs or 33 light years, and as it has a considerable number of possibly more remote but equally bright companions, it would be a good subject for a parallax campaign.

The distance of the cluster appears by the Table to be only 301 light years, and therefore to be one of our very nearest neighbors among the clusters, thereby corroborating our natural conclusions based on the brightness and scattered character of its component stars. Its parallax is $0''.0109 \pm 0''.0026$, which is perhaps not a very large uncertainty, considering the small number of stars and the large number of groups into which they are divided. The group is 4° or some twenty-five light years in diameter. The average apparent brightness of its twelve components of type A is 5.91, and their mean absolute magnitude is therefore 1.15. Their average brightness is consequently 3.65 magnitudes, or 29 times greater than that of our Sun.

WILLIAM H. PICKERING.

MARCH 5, 1918.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 207.



A NEW VARIABLE STAR OF SHORT PERIOD, $+37^{\circ} 4717$, H. V. 3435.

An examination of photographs taken at this Observatory and having several exposures, as described in H. C. 117, has been made by Miss Ashall, an assistant of Professor C. A. Chant of the Astronomical Observatory at Toronto. On one of these, she discovered a star which shows a marked change in brightness during the exposures, and proves to be a variable of unusual interest. Observations made by the writer on numerous photographs show that the range is small, only about 0.7 magn. It is remarkable, however, on account of the period of $3^h 50^m 55^s.10$, which is one of the shortest known. In the year 1913, it changed suddenly, becoming longer than before by $0^s.17$. The comparison stars are given in Table I, in which the successive columns contain the designation, the zone and number in the Bonn Durchmusterung, the right ascension for 1900, the declination for 1900, and the photographic magnitude on the International Scale.

TABLE I.
COMPARISON STARS.

Des.	DM.	R.A. 1900	Dec. 1900	Ptg.	Des.	DM.	R.A. 1900	Dec. 1900	Ptg.
Var.	$+37^{\circ} 4717$	$22^h 49.1^m$	$+37^{\circ} 23'$	..	c	$+37^{\circ} 4699$	$22^h 44.2^m$	$+38^{\circ} 0'$	9.28
a	$+37^{\circ} 4736$	54.2	$+37^{\circ} 36'$	8.78	d	$+37^{\circ} 4696$	44.1	$+37^{\circ} 35'$	9.54
b	$+36^{\circ} 4970$	53.0	$+36^{\circ} 51'$	9.07	e	$+37^{\circ} 4715$	48.6	$+37^{\circ} 14'$	9.94

The observations are given in Table II. The first column contains the Julian Day and decimal following Greenwich Mean Noon. Plates on J. D. 4594 and earlier were taken with the 8-inch Draper telescope, with exposures of about 10^m , the last three with the 4-inch Cooke, exposures 10^m , and the others with the 1-inch Cooke, exposures usually 60^m . Successive exposures on the

same date were usually 30^m each. The magnitude in the second column is given to hundredths when it is the mean of two observations, otherwise to tenths. The last two columns give the phase, corrected for the equation of light, and the residual from the light curve, expressed in hundredths of a magnitude, negative values being indicated by *Italics*. The periods to which the quantities in the last three columns correspond, differ for dates preceding and following J. D. 2,420,000, respectively, as will be explained below.

A period of 0^d.160357 was at first derived, but does not satisfy early and late observations. On plotting the residuals from the phases corresponding to the magnitudes 9.5, and fainter, in terms of the Julian Days, it was discovered that a marked change took place about J. D. 2,420,000. This is shown in Figure 1, in which horizontal and vertical distances represent Julian Days on a scale of 2000 days = 1 cm., and residuals on a scale of 0.010 days = 1 cm., respectively. Each point usually represents the mean

TABLE II.
OBSERVATIONS OF THE VARIABLE.

J. D.	Magn.	Phase.	Res.	J. D.	Magn.	Phase.	Res.	J. D.	Magn.	Phase.	Res.	J. D.	Magn.	Phase.	Res.
2354.748	9.15?	.077	03	5679.625	9.6	.129	15	6630.809	9.1	.073	08	7193.483	9.40?	.060	20
2357.709	9.70?	.151	16	5682.632	9.2	.089	02	6649.797	9.70?	.139	10	7198.520	9.5	.125	10
2368.667	9.2	.045	09	5691.631	9.50?	.107	26	6675.798	9.9	.004	02	7232.528	9.50	.135	04
2680.807	9.87	.129	42	5709.606	9.60?	.121	25	6683.832	9.6	.021	00	7409.824	9.1?	.081	08
2717.698	9.65?	.140	02	5717.502	9.9	.158	01	6717.716	9.2	.074	02	7451.579	9.8	.146	04
3092.619	10.00?	.148	19	5721.521	9.9	.009	04	6719.724	9.9	.156	02	7471.704	9.3	.066	12
3504.587	9.85	.001	04	5734.584	9.3	.082	12	6741.650	9.3	.115	01	7482.583	9.2	.041	13
3857.681	9.90	.151	04	5775.460	9.1	.064	09	6750.697	9.8	.022	22	7531.656	9.3	.045	00
4587.642	9.95	.011	12	5898.787	9.2	.076	02	6768.679	9.4?	.042	08	7546.551	9.5?	.026	02
4594.600	9.20?	.074	02	5978.726	9.95	.004	07	6776.639	9.80?	.145	06	7783.817	9.20?	.125	20
4631.481	9.25	.070	07	" .868	9.67?	.146	09	6783.631	9.30	.082	12	7803.764	9.65?	.029	18
4866.792	9.70	.140	07	6030.660	9.8	.144	08	6788.625	9.2	.105	02	7813.732	9.40?	.056	18
4882.789	9.20	.101	00	6042.602	9.3?	.060	10	6794.630	9.65	.016	07	7834.750	9.2?	.068	02
4883.676	9.50	.026	02	6061.566	9.3?	.100	10	6803.577	9.8	.143	10	7845.657	9.30?	.071	12
4932.545	9.98	.148	17	6093.571	9.5	.031	05	6821.575	9.8	.018	13	7861.676	9.2	.052	04
" .565	9.80	.008	07	6107.548	9.57?	.056	35	6829.524	9.3	.109	06	7865.625	9.8	.153	07
" .628	9.24	.071	06	6108.514	9.40?	.060	20	6860.500	9.70	.134	18	7867.664	9.40?	.107	16
" .649	9.32	.092	14	6134.462	9.63?	.028	15	7005.778	9.5?	.130	04	7879.597	9.8	.014	04
" .711	9.86	.154	02	6322.825	9.65	.137	08	7042.738	9.3?	.051	06	7891.602	9.9	.150	05
4949.622	9.25	.067	07	6418.628	9.3	.050	05	7054.741	9.4?	.027	10	7912.487	9.70	.027	20
5368.465	9.3	.056	08	6427.642	9.2	.083	02	7060.731	9.2?	.085	02	7921.486	9.3	.045	01
5564.778	9.3	.092	12	6447.594	9.8	.150	05	7111.671	9.4	.034	01	7922.491	9.2?	.089	02
5613.760	9.9	.009	04	6453.594	9.3?	.055	08	7133.530	9.2	.084	02	7927.527	10.0?	.154	12
5658.498	10.0	.008	13	6456.565	9.85	.139	25	7140.546	9.4?	.045	11	7929.488	9.5?	.029	03
5663.732	9.2	.110	05	6460.559	9.5	.124	12	7147.719	9.80?	.003	08	7931.483	9.45?	.099	25
5665.664	9.60?	.118	28	6466.561	9.57?	.031	12	7151.585	9.7	.021	10	8106.813	9.9	.001	01
5677.655	9.43?	.083	25	6485.516	9.25?	.064	06	7171.497	9.50?	.044	20	8215.619	9.1	.089	08

J. D.	Magn.	Phase.	Res.	J. D.	Magn.	Phase.	Res.	J. D.	Magn.	Phase.	Res.	J. D.	Magn.	Phase.	Res.
8230.576	9.6	.133	10	9763.454	9.80	.002	09	0107.542	9.3	.125	10	1137.531	9.4	.137	17
8267.593	9.3	.106	07	9777.517	9.2	.112	07	0115.509	9.3	.074	12	" .551	9.8	.157	09
8279.543	9.4?	.029	07	" .559	9.9	.154	02	0283.811	9.8	.157	08	" .572	9.6	.018	07
8302.480	9.4	.032	04	9917.819	9.1	.101	10	0300.814	9.7	.003	18	" .593	9.3	.039	05
8520.829	9.6?	.139	00	9971.834	9.4?	.035	00	0309.801	9.8?	.011	03	" .614	9.1	.060	10
8532.772	9.3	.056	08	9992.773	9.7	.013	08	0371.733	9.25	.049	01	" .635	9.1	.081	08
8540.711	9.5	.139	10	9999.751	9.2?	.097	01	0380.790	9.3	.125	10	" .656	9.3	.102	09
8547.712	9.1?	.085	08	0000.723	9.2	.107	03	0384.762	9.25	.088	07	" .676	9.5?	.122	14
8567.716	9.3	.044	00	0005.719	9.60?	.132	12	0388.645	9.3?	.123	07	1141.676	9.1	.113	18
8580.670	9.73?	.009	13	0034.510	9.25	.059	05	0389.661	9.7?	.017	00	1164.491	9.9	.157	01
8589.750	9.2	.109	04	" .531	9.20	.080	02	0391.673	9.3?	.104	08	1171.613	9.3	.063	11
8640.626	9.9	.149	07	" .552	9.05	.101	15	0393.667	9.70	.013	08	1183.546	9.6	.128	16
8645.524	9.1	.075	08	" .573	9.30	.122	06	0449.450	9.83	.152	04	1193.447	9.10	.085	08
8665.574	9.2	.080	02	" .594	9.60	.143	10	" .468	9.77	.010	08	" .468	9.25	.106	02
8672.555	9.70	.004	13	" .615	9.90	.004	02	" .489	9.40	.031	05	" .489	9.55	.127	12
8682.508	9.8	.015	06	" .635	9.50	.024	06	" .510	9.30	.052	06	" .510	9.95	.148	14
8684.488	9.3	.070	12	" .656	9.30	.045	01	" .531	9.13	.073	03	" .531	9.85	.009	01
8827.827	9.2	.051	04	" .677	9.05	.066	13	" .551	9.10	.093	08	" .551	9.50	.029	03
8882.812	9.20?	.038	16	" .698	9.10	.087	08	" .572	9.23	.114	05	" .572	9.25	.050	00
8884.796	9.30	.097	11	" .715	9.20	.104	02	" .593	9.50	.135	04	" .593	9.05	.071	13
8904.754	9.8	.013	02	0035.513	9.25	.100	05	" .614	9.87	.156	01	" .614	9.20	.092	02
8911.544	9.1	.068	08	" .531	9.20	.118	12	" .635	9.73	.017	03	" .635	9.20	.113	08
8924.746	9.4?	.121	05	" .552	9.45	.139	15	0453.544	9.3	.077	12	1199.527	9.2	.072	02
8936.748	9.3	.097	11	" .573	9.70	.000	19	0459.487	9.3?	.086	12	1227.512	9.8	.002	09
8943.671	9.5	.125	10	" .594	9.45	.021	15	0485.503	9.43	.122	07	1240.486	9.6	.146	16
8948.633	9.25	.116	05	" .615	9.25	.042	07	0548.493	9.15	.086	03	1262.482	9.90	.012	09
8976.561	9.70	.142	03	" .635	9.20	.062	01	0661.809	9.3?	.032	14	1404.818	9.3?	.113	02
8977.576	9.5	.034	09	" .656	9.10	.083	08	0735.776	9.1	.079	08	1484.715	9.9	.155	02
8992.644	9.4?	.027	10	" .677	9.25	.104	03	0771.727	9.3?	.100	05	1494.661	9.9	.158	01
9013.450	9.8	.144	08	" .698	9.35	.127	08	0789.592	9.5?	.016	22	1503.627	9.7	.145	04
9022.492	9.3	.046	02	0036.651	9.25	.116	05	0862.439	9.2	.054	03	" .673	9.5?	.031	05
9036.567	9.8	.007	07	" .756	9.1?	.061	10	" .478	9.3?	.093	12	1506.603	9.1	.074	08
9041.471	9.3	.100	10	0038.492	9.45	.033	02	0869.503	9.3?	.063	11	1515.629	9.2	.119	13
9237.812	9.9	.010	05	" .510	9.20	.051	04	0897.476	9.4?	.131	07	1544.559	9.6?	.023	03
9240.779	9.2	.090	02	" .531	9.20	.072	02	0983.844	9.1	.063	09	1546.468	9.72?	.010	13
9244.773	9.2	.076	02	" .552	9.1?	.093	08	1038.816	9.3	.037	07	" .489	9.40?	.031	05
9263.812	9.4?	.033	03	" .573	9.20	.114	08	1078.835	9.15	.130	31	" .510	9.20?	.052	04
9281.725	9.7	.148	11	" .594	9.40	.135	14	1090.816	9.2	.086	02	" .531	9.13?	.073	05
9283.703	9.3	.041	03	" .615	9.80	.156	08	1091.747	9.2?	.055	02	" .551	9.15?	.093	03
9290.740	9.55?	.021	05	" .635	9.50	.016	22	1121.743	9.10?	.064	09	" .572	9.28?	.114	00
9317.624	9.3?	.125	10	" .656	9.35	.037	02	1126.804	10.0	.154	12	" .593	9.60?	.135	06
9336.597	9.7	.016	02	" .677	9.25	.057	04	1133.510	9.30	.125	10	" .614	9.88?	.156	00
9356.590	9.55?	.124	17	" .698	9.05	.078	13	" .531	9.90	.146	14	" .635	9.85?	.017	15
9567.786	9.4?	.128	04	0053.627	9.1	.094	08	" .551	9.95	.006	07	" .656	9.48?	.038	11
9682.625	9.8?	.156	08	" .659	9.5?	.126	09	" .571	9.35	.027	15	1617.810	9.50	.139	10
9690.628	9.6?	.141	05	0072.530	9.2?	.074	02	" .593	9.20	.047	08	" .812	9.80?	.141	15
9691.609	9.8	.000	09	0078.513	9.4?	.123	03	" .614	9.10	.068	08	" .822	9.85	.151	01
9707.582	9.2	.098	01	0079.559	9.2	.047	08	" .635	9.15	.089	03				
9713.547	9.4?	.129	05	0081.555	9.4	.119	07	" .656	9.25	.110	00				
9717.562	9.6	.134	08	0107.500	9.2	.083	02	1137.510	9.3	.116	00				

derived from observations extending over several hundred days, but near the critical time of change, the intervals are smaller. Fortunately, about this time, there

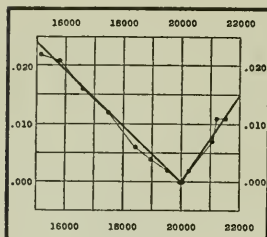


FIG. 1.

are several plates having multiple exposures, as explained on page 1. The periods before and after J. D. 2,420,000 are represented by the formulae for times of minima, J. D. 2,410,000.005 + $0^d.1603562 E$, and J. D. 2,410,000.040 + $0^d.1603582 E$, respectively. There is no evidence of a secondary minimum.

The light curve is given in Figure 2. Each point represents the mean of five images, arranged in the order of phase.

Horizontal and vertical distances are on a scale of 0.040 days = 1 cm., and 0.40 magn. = 1 cm., respectively. Sixteen images whose residuals, as given in the last column of Table II, are ± 20 , or more, were omitted in taking the means. The accidental errors of

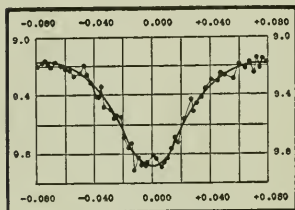


FIG. 2.

observation are unusually large, as all of the comparison stars but one are so far from the variable that the images are differently affected by their distances from the centres of the plates. Also, on account of the rapid changes in light, there are systematic errors depending on the length of exposure. The average deviation of a single normal point from the light curve is ± 0.029 magn., of a single image, ± 0.080 magn., or omitting the 16 largest residuals, ± 0.071 magn. The residuals tend to be positive for early, and negative for late plates. This may indicate a slight change in the range of brightness.

HENRIETTA S. LEAVITT.

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CIRCULAR 208.

THE NEW STAR, 184300, NOVA AQUILAE, NO. 3.

THE first record of Nova Aquilae, No. 3, is on a photograph taken here on May 22, 1888. Its photographic magnitude was then 10.5. It was found on 405 subsequent photographs, extending to June 3, 1918, to be of nearly the same brightness. It underwent small, but undoubted, changes in light, becoming somewhat fainter in 1909. It also appears in the Alger Zone on August 12, 1892, and June 26, 1895, and on 54 photographs taken by Professor Barnard, the first being on June 29, 1892.

June 4, 5, and 6, 1918, were cloudy here, but three photographs were obtained on June 7, 1918, when it was of the sixth magnitude. The following night when its visual magnitude was 0.8, it was discovered independently by a large number of persons. Owing to the difference in longitude it was first seen in Europe while it was still below the horizon in America. From the reports so far received here, it was first seen by M. Luizet in Lyons at 8^h 40^m, G. M. T. The first observation in America appears to be that of Mr. Vincent Francis of New Bedford, Mass., at 13^h 00^m, G. M. T. The local times in the two cases were 8^h 59^m and 8^h 17^m. Since then, 523 observations of its brightness have been received from 71 persons. Although many of them were inexperienced in work of this kind, the general agreement is excellent. The average deviation of all is ± 0.14 magn., but this includes 29 observations when it was brighter than any star above the horizon, and the comparison was therefore uncertain. Their average deviation is ± 0.37 magn. Omitting these, the average deviation is ± 0.12 , while the 136 observations between the third and fourth magnitudes give an average deviation of only ± 0.09 .

Photometric magnitudes have been determined of nearly all stars of the seventh magnitude, or brighter. Any of these may accordingly be used as comparison stars. The map contained in H. B. 661 will be found convenient, when the Nova is of the sixth magnitude, or brighter, since it gives the pho-

tometric magnitudes of all adjacent stars to the magnitude 6.4. A list of comparison stars is given in Table I, including those which may be used when the Nova becomes faint. The successive columns give the usual desig-

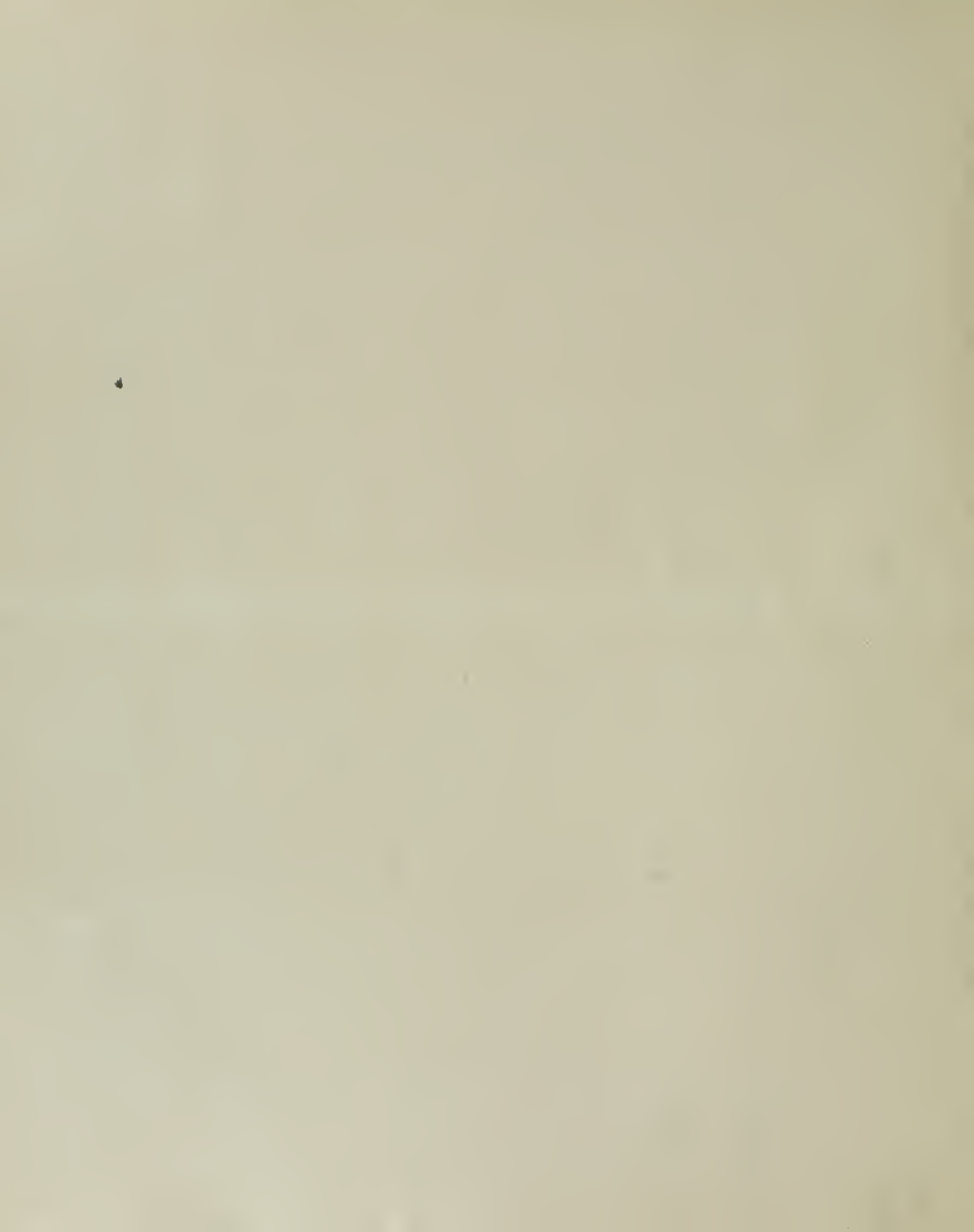
TABLE I.
COMPARISON STARS.

Name.	D. M.	R.A. 1900	Dec. 1900.	Ptm.	Name.	D. M.	R.A. 1900	Dec. 1900.	Ptm.
Nova Aquilae	..	^{h.} 18 ^{m.} 43.8	[°] + 0 ['] 29	..	θ Serpentis	+ 4°	^{h.} 3916 ^{m.} 18 51.2	[°] + 4 ['] 4	4.10
α Canis Maj.	-16° 1591	6 40.7	-16 35	1.58	i Aquilae	- 5°	4840 18 56.3	- 5 53	4.15
α Carinae	-52° 914	6 21.7	-52 38	0.86	ε Aquilae	+14°	3736 18 55.1	+14 56	4.21
α Lyrae	+38° 3238	18 33.6	+38 41	0.14	β Scuti	- 4°	4582 18 41.9	- 4 51	4.47
α Bootis	+19° 2777	14 11.1	+19 42	0.24	η Scuti	- 6°	4976 18 51.7	- 5 58	5.04
α Aquilae	+ 8° 4236	19 45.9	+ 8 36	0.89	4 Aquilae	+ 1°	3766 18 39.8	+ 1 57	5.04
α Virginis	-10° 3672	13 19.9	-10 38	1.21	64 Serpentis	+ 2°	3738 18 52.3	+ 2 26	5.65
α Scorpii	-26° 11359	16 23.3	-26 13	1.22	5 Aquilae	- 1°	3559 18 41.3	- 1 3	5.68
α Cygni	+44° 3541	20 38.0	+44 55	1.33	e Serpentis	- 0°	3521 18 32.5	- 0 24	5.80
α Leonis	+12° 2149	10 3.0	+12 27	1.34	8 Aquilae	- 3°	4392 18 46.1	- 3 26	6.04
η Ursae Maj.	+50° 2027	13 43.6	+49 49	1.91	- Aquilae	+ 0°	4027 18 44.5	+ 0 44	6.26
ε Sagittarii	-34° 12784	18 17.5	-34 26	1.95	"	- 0°	3543 18 39.8	- 0 29	6.80
α Ursae Min.	+88° 8	1 22.6	+88 46	2.12	"	+ 0°	4055 18 50.7	+ 0 8	7.73
α Ophiuchi	+12° 3252	17 30.3	+12 38	2.14	"	+ 0°	4045 18 48.4	+ 0 45	8.02
γ Cygni	+39° 4159	20 18.6	+39 56	2.32	"	+ 0°	4035 18 46.2	+ 0 43	8.11
γ Aquilae	+10° 4043	19 41.5	+10 22	2.80	"	+ 0°	4023 18 43.6	+ 0 25	8.65
δ Cygni	+44° 3234	19 41.9	+44 53	2.97	"	+ 0°	4033 18 45.9	+ 0 8	8.68
ζ Aquilae	+13° 3899	19 0.8	+13 43	3.02	"	+ 0°	4028 18 44.8	+ 0 26	8.92
β Cygni	+27° 3410	19 26.7	+27 45	3.10	"	+ 0°	4026 18 43.9	+ 0 11	8.96
η Serpentis	- 2° 4599	18 16.1	- 2 55	3.42	"	- 0°	3562 18 43.9	+ 0 1	9.28
δ Aquilae	+ 2° 3879	19 20.5	+ 2 55	3.44	"	+ 0°	4022 18 43.6	+ 0 33	9.90
λ Aquilae	- 5° 4876	19 0.9	- 5 2	3.55	"	+ 0°	4020 18 42.9	+ 0 29	10.26
β Aquilae	+ 6° 4357	19 50.4	+ 6 9	3.90	"	+ 0°	4024 18 43.9	+ 0 6	10.38

nation, the number in the Durchmusterung, the right ascension for 1900, the declination for 1900, and the photometric magnitude.

The position of these stars is shown in Fig. 1 which is enlarged from the Durchmusterung Chart. The variations in light of the Nova are shown in Fig. 2. Since it began to fade, its light has fluctuated by half a magnitude at intervals of about ten days. These changes are much less pronounced than those of Nova Persei, No. 2.

Table II gives in successive columns the date, the Julian Day and decimal, the number of observations and the mean visual magnitude. The first



and second magnitudes are, however, photographic, and only approximate. It will be noticed that since the star became bright, observations have been obtained somewhere on every night.

The first photograph obtained here of the spectrum of the Nova was taken on June 9, 17^h 43^m, G. M. T. with the 8-inch Draper Telescope and an

TABLE II.
PROVISIONAL LIGHT CURVE.

Date.	J. D.	No.	Magn.	Date.	J. D.	No.	Magn.	Date.	J. D.	No.	Magn.
1918.				1918.				1918.			
June 3	1748.7	1	10.5	June 13	1758.7	11	1.19	July 3	1778.6	16	3.22
" 7	1752.8	3	6	" 14	1759.6	24	1.47	" 4	1779.6	5	3.00
" 8	1753.4	12	1.12	" 15	1760.6	17	1.62	" 5	1780.7	3	3.40
" "	1753.5	11	1.06	" 16	1761.6	15	1.98	" 6	1781.6	1	3.60
" "	1753.6	10	0.72	" 17	1762.7	4	2.05	" 7	1782.6	6	3.42
" "	1753.7	7	0.71	" 18	1763.6	20	2.16	" 8	1783.6	11	3.47
" "	1753.8	2	0.45	" 19	1764.7	13	2.29	" 9	1784.6	5	3.60
" 9	1754.4	11	0.32	" 20	1765.6	21	2.38	" 10	1785.6	9	3.83
" "	1754.6	8	0.39	" 21	1766.7	1	2.60	" 11	1786.6	3	4.00
" "	1754.7	9	0.90	" 22	1767.7	4	2.80	" 12	1787.6	10	4.00
" "	1754.8	3	1.50	" 23	1768.7	5	2.98	" 13	1788.7	2	3.80
" 10	1755.4	11	0.04	" 24	1769.6	17	2.82	" 14	1789.6	6	3.56
" "	1755.5	4	0.15	" 25	1770.6	18	2.99	" 15	1790.6	6	3.53
" "	1755.7	6	0.12	" 26	1771.6	18	3.40	" 16	1791.6	4	3.61
" "	1755.8	3	0.50	" 27	1772.6	8	3.78	" 17	1792.7	2	3.60
" 11	1756.5	8	0.48	" 28	1773.7	3	3.73	" 18	1793.6	4	3.65
" "	1756.7	8	0.30	" 29	1774.6	8	3.76	" 19	1794.6	3	3.77
" 12	1757.5	14	0.67	" 30	1775.6	9	3.47	" 20	1795.6	7	4.13
" "	1757.7	20	0.80	July 1	1776.7	8	3.28	" 21	1796.6	12	4.26
" 13	1758.5	19	1.09	" 2	1777.6	13	3.23	" 22	1797.6	1	4.22

objective prism. Isochromatic plates were used. The spectrum was of Class A3, with the lines narrow, as in α Cygni. The night of June 10 was cloudy, and on June 11, the spectrum was of the normal Nova type. Fortunately the spectrum was photographed at the Yerkes Observatory and elsewhere throughout the night of June 9, and early in the evening of June 10. These plates showed that the change took place during the daytime of June 10, when the Nova was below the horizon of America. It is hoped that this gap may be partly filled by some European astronomers.

Another series of photographs of the spectrum has been taken with plates stained with pinaeyanol with an objective prism 24 inches in diameter on the

24-inch Reflector. These plates show the line $H\alpha$ as the brightest line in the spectrum.

A detailed examination of the spectrum plates is being made by Miss Cannon, who notes the following changes:—On June 14, three dark lines of reversal were situated on the bright bands. On June 16, there was little trace of the dark lines, $H\beta$ and $H\gamma$, but at the position of $H\delta$, there was a double dark line, the portion of shorter wave length being much stronger than that of greater wave length. This increase is probably due to the line 4059, which has been found to be subject to great variations in other Novae, as Nova Persei, No. 2, H. A. 56, 46, Nova Geminorum, No. 2, H. C. 176, Nova Sagittarii, No. 1, and Nova Lacertae, H.A. 76, 36. On June 25, 1918, the line 4059, was the strongest dark line in the spectrum of Nova Aquilae, No. 3, but on June 26 and 29, it was bright. It was dark again on July 2, 3, 4, 7, and 8, and absent or barely seen as a bright line on July 10, 11, and 12. These changes appear to be connected with the oscillations in the light of the star, as may be seen from the curve in Fig. 2. Progressive changes have occurred in the bright bands 4650 and 5018, perhaps joined with 5007. On July 11, the bright $H\gamma$ was considerably wider towards the red, which may be due to the appearance of the nebular band 4363.

The photometric measures and the compilations of the visual magnitudes have been made by Mr. Leon Campbell. A careful study of the photographic magnitudes is being made by Miss Leavitt.

EDWARD C. PICKERING.

JULY 23, 1918.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 209.

THE SPECTRUM OF NOVA MONOCEROTIS, 072106.

The cablegram from Copenhagen announcing the discovery of this new star by Wolf of Heidelberg was received here on February 21, 1918. An examination of the Harvard collection of photographs showed that the object was not visible, and must have been fainter than magnitude 10.8 on December 22, 1917, and that on January 1, 1918, it was present and had the photographic magnitude 5.4.

The first spectrum plate obtained here was on February 21, 1918, when the photographic magnitude was 9.5. From that time until April 6, 1918, photographs of the spectrum were taken. The instrument used was the 24-inch Reflector, whose focal length is 11 feet. A prism having an aperture of 24 inches, and an angle of about 6° , was placed at the end of the tube, and gave spectra of such dispersion that the interval between $H\alpha$ and $H\beta$ is 1.4 mm. and between $H\beta$ and $H\epsilon$ is 1.7 mm. Twenty-one of the plates were stained with pinacyanol and included the region of $H\alpha$. One ordinary plate was used, and the others were isochromatic.

February 21, 1918. Four photographs were taken. For the first two, plates stained with pinacyanol and a yellow screen were used. The third and fourth, were made on a Hammer Special ordinary plate, and an isochromatic plate. The exposures were 21^m, 10^m, 7^m, and 7^m, respectively. On the plates stained with pinacyanol, bright lines are present at 5007, 5630, 5750, and $H\alpha$, the relative intensities being 1, 2, 1, 10. The isochromatic plate shows eight bright bands, of which the broad band comprising $H\gamma$ and 4363 is by far the brightest. The wave lengths of bands 4520, 5440, 5630, and 5677 are only approximate, especially for the second and fourth lines, which are faint. The following intensities of the relative brightness of the bands were estimated on the isochromatic plates: $H\gamma$, 2; $H\epsilon$, 2; $H\delta$, 5; $H\gamma$ and 4363 together, 10; 4520, 1; 4650, 4; $H\beta$, 2; 5007, 3; 5440, 1; and 5630, 3. Band 4650 may include 4686, and 5007 may include 4959.

February 26, 1918. Two photographs were taken on plates stained with pinacyanol. The exposures were 21^m and 10^m . The plates are poor. They show that $H\alpha$ is at least 1.5 as bright as the compound line, $H\gamma$ and 4363. Since it is probable that nearly all of the brightness of the latter band is due to the nebular line, it will hereafter be designated 4363.

February 27, 1918. Two photographs were taken on plates stained with pinacyanol. The exposures were 11^m and 23^m . $H\alpha$ is still about 1.5 as bright as 4363. The band 5007 has become nearly equal to 4650.

March 2, 1918. Two photographs were taken, the first, on a plate stained with pinacyanol and the second, on an isochromatic plate. The exposures were 55^m and 53^m . On the first plate, $H\alpha$ is still the most intense bright line, although not more than 1.2 as bright as 4363. The band 5007 is equal to 4640.

March 7, 1918. One photograph, having an exposure of 43^m , was taken on a plate stained with pinacyanol. The quality is poor. $H\alpha$ is the strongest bright line.

March 8, 1918. One photograph, having an exposure of 38^m , was taken on a plate stained with pinacyanol. $H\alpha$ is again much brighter than 4363. The plate is thin, and it is uncertain whether this increase in the brightness of $H\alpha$ is real. The line 5007 is distinctly brighter than 4650.

March 11 and 15, 1918. Two photographs were taken on each evening, the plates being stained with pinacyanol. The exposures were 35^m and 40^m on March 11, and 8^m and 37^m on March 15. $H\alpha$ is only slightly brighter than 4363. The bright bands and their intensities are as follows, — $H\delta$, 1; 4363, 10; 4650, 3; $H\beta$, 1; 5007, 5; $H\alpha$, 11.

March 16, 1918. Two photographs were taken on plates stained with pinacyanol. The exposures were 58^m and 26^m . $H\alpha$ and 4363 are approximately equal, while 5007 is about 0.7 as bright as $H\alpha$. Band 4650 has become much fainter.

March 18, 1918. One photograph, having an exposure of 60^m , was taken on a plate stained with pinacyanol. The spectrum is the same as on March 16.

March 19, 1918. One photograph, having an exposure of 26^m , was taken on a plate stained with pinacyanol. $H\alpha$ appears to be brighter than 4363. The lines present and their intensities are, 4363, 10; 4650, 2; $H\beta$, 1; 5007, 7; 5630, 1; $H\alpha$, 15.

March 20 and 23, 1918. One photograph was taken on each evening, the plates being stained with pinacyanol. The exposures were 31^m and 27^m . The

three bright bands, 4363, 5007, and $H\alpha$, are nearly equal. Band 4650 is much fainter than the other bands.

March 26 and 28, 1918. One photograph was taken on each evening, the plates being stained with pinaeyanol. The exposures were 28^m and 60^m. $H\alpha$ is again much more intense than 4363 or 5007, which are equal. Bands 4650 and 5630 are barely seen.

March 29 and 30, April 2 and 5, 1918. On photograph was taken each evening on isochromatic plates. The exposures were 59^m, 64^m, 49^m, and 61^m, respectively. They show the bands 4363 and 5007 to be nearly equal, and 4650 to be very faint.

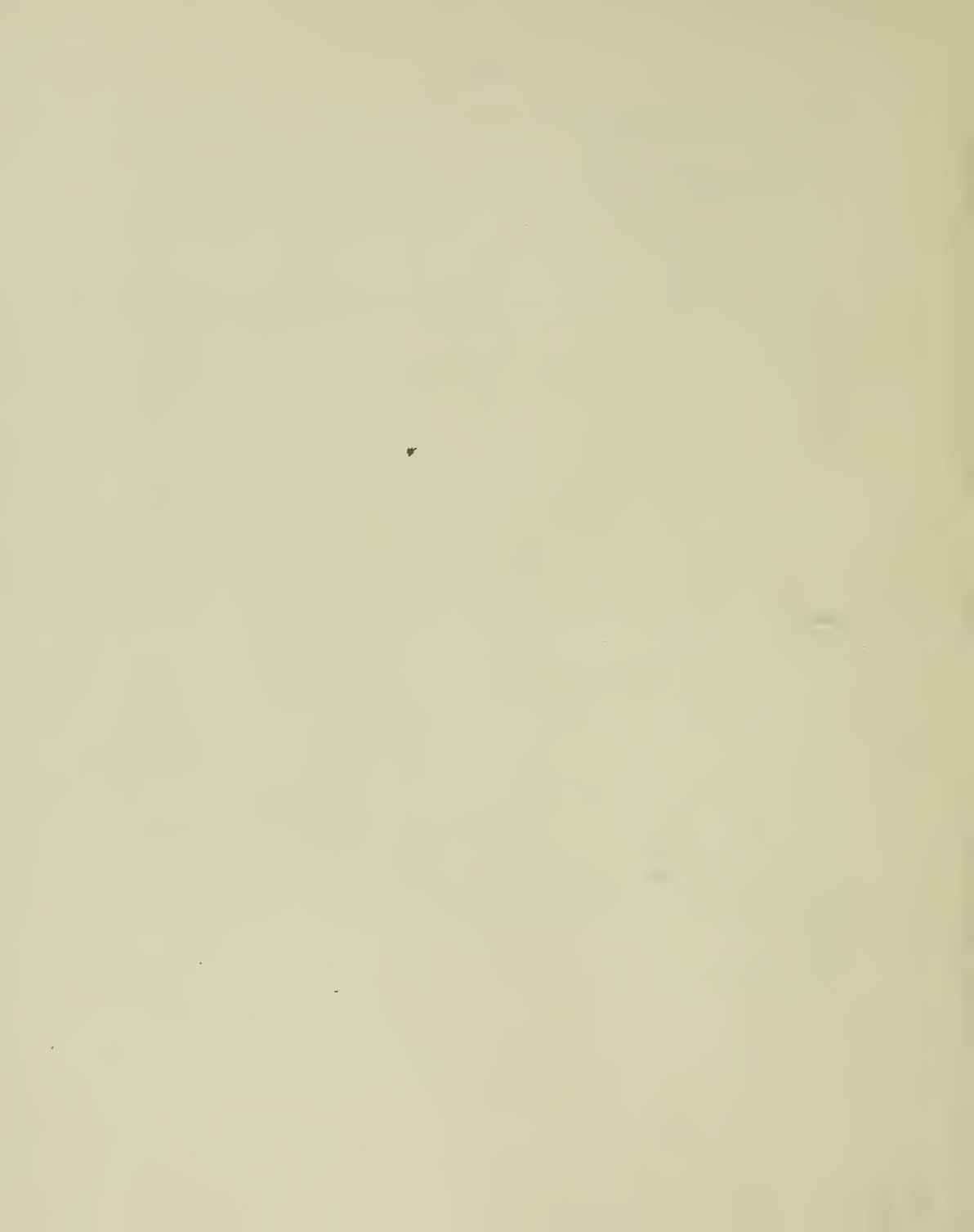
April 6, 1918. One photograph, having an exposure of 81^m, was taken on an isochromatic plate. The three bright bands present and their intensities are 4363, 10; 4650, 1; 5007, 12.

A summary of the preceding observations is given below:—

The first known image of Nova Monocerotis appears on a photograph taken at this Observatory on January 1, 1918, when the photographic magnitude was 5.4. It was invisible on a photograph taken December 22, 1917, and showing stars of the magnitude 10.8. When the first photograph of the spectrum was obtained here on February 21, 1918, it was thus certainly 51 days, and possibly 61 days, after the outburst. The brightness had faded at least 4.1 magnitudes. The spectrum consisted of bright lines and had reached the nebular stage. $H\alpha$ was the most intense bright line and 4363 was next in order of brightness. The nebular line 5007 increased gradually from less than 0.3 of the intensity of 4363 on February 21, to equality with it on March 20, while on April 6, it was the most intense bright line visible on an isochromatic plate. Band 4650 likewise steadily decreased until it was barely seen on April 6. Apparent fluctuations appeared in the brightness of $H\alpha$ as compared with 4363. On March 2, 11, 16, 18, 20, and 23, the line $H\alpha$ appeared equal or only slightly brighter than 4363, while on February 26, 27, March 7, 8, 19, 26, and 28, it was at least 1.5 as bright as 4363. The photographic magnitude of the Nova diminished from 9.4 on February 21 to about 10.1 on April 6, 1918.

ANNIE J. CANNON.

SEPTEMBER 17, 1918.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 210.

ILLUSTRATIONS OF NOVA AQUILAE, NO. 3, 184300.

Photographs of Nova Aquilae, No. 3, described in H. C. 208, are shown in the accompanying plate. They are all on the scale of $20'' = 1$ mm. and represent a region $30'$ by $35'$ with the Nova near the centre.

Figure 1 is from a negative taken with the 8-inch Bache Telescope at $18^h 55^m$ G. M. T. on May 22, 1888. The exposure was 22^m . This negative is catalogued in H.A. 26, 38 as B 2655. Two other photographs of the object, B 2656 and B 3013, were taken on May 22 and October 18 of the same year.

Figure 2 is from a negative taken with the 16-inch Metcalf Telescope at $19^h 14^m$ G. M. T. on June 3, 1918. The exposure was 10^m . The brightness is nearly the same as in Figure 1, about 10.9 magn., but as the intermediate photographs show slight changes in light, its identity with the Nova is undoubted. It is distinctly fainter than the two stars on the right, and much fainter than the star $+0^\circ 4027$, in the upper left-hand corner, whose photometric magnitude is 6.26. The images above and below each bright star are formed by a grating placed in front of the objective. This appears to be the best method yet devised for determining photographic magnitudes. The Nova was also faint on photographs taken May 14, 18, and 20, 1918.

Figure 3 is from a negative taken with the 16-inch Metcalf Telescope at $18^h 50^m$ G. M. T. on June 7, 1918. The exposure was 10^m . The Nova was then 6.2, or approximately of the brightness of $+0^\circ 4027$. Photographs were taken with two other instruments on the same evening at $18^h 20^m$ and $18^h 22^m$. The magnitude of the Nova on these plates was 6.7. They show the rapid increase in the next half hour.

Figure 4 is from a negative taken with the 16-inch Metcalf Telescope at $19^h 55^m$ G. M. T. on June 8, 1918. The exposure was 10^m . The star was still nearly two magnitudes below its maximum brightness which occurred the following day, when passing clouds prevented the observation of its magnitude here.



FIG. 1. MAY 22, 1888.



FIG. 2. JUNE 3, 1918.



FIG. 3. JUNE 7, 1918.



FIG. 4. JUNE 8, 1918.

NOVA AQUILAE, NO. 3.

On June 5, an important photograph by Wolf shows that the Nova was still faint, and of its normal brightness. On June 6, Messrs. Hopmann, Lefebvre, de Roy, Paeker, Adone, Luyten, Kienle, and Miss Cook, who were making visual observations in the vicinity of the Nova, are satisfied that it was not then bright. On June 7, the same result was attained at $8^h 25^m$, G. M. T. by Drummond; at $10^h 05^m$ by Denning; at $11^h 0^m$ by Kohl; at $11^h 22^m$ by de Roy; at $15^h 20^m$ by L. Campbell; at about 19^h by Sullivan. On the other hand, it is claimed to have been seen as bright on June 6 by Breson and Longbottom, and on June 7 at $8^h 45^m$ by Laskowski; at $9^h 30^m$ by Kacz; at 10^h by Breson; at $12^h 45^m$ by Piper. Others claimed to have seen it even earlier. It is difficult to account for these observations of the Nova when the photographs show that it was almost certainly faint. The probable explanation is an error in the date, especially when the observer delayed his announcement for several days. Another explanation is an error in identification. The configuration of α Bootis, α Virginis, and Mars was nearly the same as that of α Lyrae, α Aquilae, and the Nova. In fact, in one case, this mistake is known to have been made. The hypothesis remains that the star was alternately bright and faint at short intervals. No other Nova is known to have undergone such changes.

The possibility of an error here in the date is excluded by the fact that the date was recorded independently by three observers. That it was clear on June 7, and cloudy on June 4, 5, and 6, is proved photographically by the pole-star recorder, and by the meteorological record.

A discussion of the light curve of this object is now being prepared by Mr. Leon Campbell in a form similar to that of Nova Persei, No. 2, in H.A. 48, 39, and that of Nova Geminorum, No. 2, in H.A. 76, 192. Observers are requested to send their observations here, especially those of June and July, so that they can be included in this work. So far, 2490 observations have been received from 202 observers. It is proposed to include observations received here up to January 1, 1919, when the Nova can no longer be seen as it approaches conjunction with the Sun.

EDWARD C. PICKERING.

SEPTEMBER 17, 1918.

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HARVARD COLLEGE OBSERVATORY.

CIRCULAR 211.

GLOBULAR CLUSTERS.

THE study of the globular clusters has proved increasingly attractive to astronomers. This is well shown in recent years by the work of Barnard, Eddington, Plummer, Shapley, Strömngren, von Zeipel, and others. In addition to the importance which they have as special problems, the writings of these investigators have thrown interesting light on the structure of the stellar system as a whole.

The variable stars in these clusters form one of the problems presented. Their study was begun at this Observatory a quarter of a century ago. It may be fitting at this time to point out the present condition of this work, and the desirability of further cooperation, or the independent extension of the investigation, by other observatories.

A provisional list of globular clusters was given in H.A. 76, No. 4. It is stated therein that the number of such objects now known is about 76. The precise number will vary with each observer, according to his definition of a globular cluster, especially, since no cluster is exactly globular. As this number, however, has not been materially increased by the remarkable astronomical development of recent years, a definitive survey of the subject may be reasonably expected within a short time. Far-reaching conclusions can then be safely drawn, which at present must be based on incomplete data.

A list of 23 clusters, which were examined for variables about 25 years ago at Arequipa, is given in H.A. 38, page 2. Of these, 17 clusters contain 2, or more, known variables. Studies of 4 of these clusters have already been published, and work on 4 others has made some progress. A discussion of the variable stars in ω Centauri has been given in H.A. 38, and of those in Messier 3 and 5, in H.A. 78, Parts 1 and 2, respectively. A discussion of Messier 15 is already in print and will be issued soon as H.A. 78, Part 3. Attention should be called to the fact that the number of variables in Messier 3 and some other clusters has been materially increased by Dr. Shapley; also, that the discussions already carried out have been greatly assisted by the loan of photographs made with the great reflectors of the Lick and Mount Wil-

son Observatories. A discussion has been begun of the variables in N. G. C. 6656, Messier 22, and material exists at this Observatory for the study of N. G. C. 104, 47 Tucanae, and N. G. C. 362. Nearly enough photographs have also been obtained of N. G. C. 6266. Nine out of the 17 clusters thus remain unprovided for, to which must be added N. G. C. 6121 and 3201 in which many variables have been found by Miss Leavitt and Miss Woods at this Observatory. These 11 clusters are given in the following table, in which successive columns contain the N. G. C. number, the designation, the right ascension and declination for 1900, the number of variables found on the Harvard plates, and the number of suitable photographs now available at this Observatory. The photographs referred to in the last column were made with the 13-inch Boyden Telescope at Arequipa. This instrument gives admirable results, but owing to

TABLE I.
GLOBULAR CLUSTERS FOR WHICH PHOTOGRAPHS ARE NEEDED.

N.G.C.	Desig.	R.A. 1900.	Dec. 1900.	No. Var.	Plates Avail.	N.G.C.	Desig.	R.A. 1900.	Dec. 1900.	No. Var.	Plates Avail.
		<i>h.</i> <i>m.</i>	<i>°</i> <i>'</i>					<i>h.</i> <i>m.</i>	<i>°</i> <i>'</i>		
1904	M 79	5 20.1	-24 37	5	6	6626	M 28	18 18.4	-24 55	9	22
3201	Δ 445	10 13.5	-45 54	60	7	6723	Δ 573	18 52.8	-36 46	16	20
6093	M 80	16 11.1	-22 44	2	5	6809	M 55	19 33.7	-31 10	2	4
6121	M 4	16 17.5	-26 17	33	5	7089	M 2	21 28.3	- 1 16	10	15
6205	M 13	16 38.1	+36 39	2	13	7099	M 30	21 34.7	-23 38	3	9
6397	Δ 366	17 32.5	-53 37	2	5						

its small size and the faintness of the stars in most of these clusters, long exposures amounting to 100^m, or more, are needed. This involves an immense amount of labor. Neither are the photographs obtained as useful as those of short exposure made with more powerful telescopes. With the great reflectors now in use the exposures needed are only a few minutes, in some cases not more than 2^m or 3^m. For a satisfactory discussion of the variables, a minimum of 50 photographs is needed. A series of exposures extending over as many hours as possible on one or more nights, taken at intervals of half an hour, or less, with occasional plates at other times, supplemented by the photographs already made at this Observatory, provides the most desirable material. Sequences of comparison stars have been selected and the determination of their photographic magnitudes has been begun. The Director of this Observatory is ready to furnish all available material to any observer who can obtain the additional photographs necessary for the completion of

the work, and who desires to make the discussion himself, or he will be glad to obtain on loan photographs of these clusters, whether few or many, for discussion by the writer.

In Table II is given a list of especially interesting clusters which are in need of systematic examination for the presence of variable stars. The data are extracted from Table I in H.A. 76, No. 4. Negative results would be only less valuable than positive. For a satisfactory determination of the presence or absence of such stars, from 5 to 10 good photographs are needed.

TABLE II.
GLOBULAR CLUSTERS NEEDING EXAMINATION FOR VARIABLES.

N.G.C.	Desig.	R.A. 1900.	Dec. 1900.	No. Stars.	N.G.C.	Desig.	R.A. 1900.	Dec. 1900.	No. Stars.
		<i>h.</i> <i>m.</i>	<i>°</i> <i>'</i>				<i>h.</i> <i>m.</i>	<i>°</i> <i>'</i>	
288	..	0 47.8	-27 8	150	6273	M 19	16 56.4	-26 7	750
1851	Δ 508	5 10.8	-40 9	400	6293	..	17 4.0	-26 26	150
2808	Δ 265	9 10.0	-64 27	1000	6333	M 9	17 13.3	-18 25	200
4372	Δ 67	12 20.1	-72 7	250	6341	M 92	17 14.1	+43 15	100
4590	M 68	12 34.2	-26 12	150	6362	Δ 225	17 21.5	-66 58	100
4833	Δ 164	12 52.7	-70 20	250	6541	Δ 473	18 0.8	-43 44	350
5024	M 53	13 8.0	+18 42	350	6584	Δ 376	18 10.6	-52 15	75
5286	Δ 388	13 40.1	-50 52	300	6637	M 69	18 24.8	-32 25	100
6218	M 12	16 42.0	- 1 46	300	6681	M 70	18 36.7	-32 23	100
6254	M 10	16 51.9	- 3 57	700					

The first four columns give the N. G. C. number, the designation, and the right ascension and declination for 1900. The last column gives the number of stars in the cluster, as shown on the Harvard photographs. The magnitudes of the stars are more or less the same in all these clusters. Those referred to in the table lie in general between the thirteenth and sixteenth magnitudes. Fainter stars in great numbers no doubt exist in many of these clusters, which would be shown by long exposures with powerful telescopes. All the variables at present known in the globular clusters belong to the brighter stars. The examination of stars fainter than the sixteenth magnitude has not, so far, revealed the presence of variables among them. A systematic examination of the stars in all the globular clusters, between the sixteenth and twentieth magnitudes, as soon as this is possible, appears to be very desirable.

SOLON I. BAILEY.

OCTOBER 31, 1918.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 212.

MAXIMA IN 1919 OF VARIABLE STARS OF LONG PERIOD.

OWING to the irregularity in the changes in light of variable stars of long period, it is impossible to predict the times of maxima with accuracy. Mr. Leon Campbell computed the times of maxima in 1917 and 1918, by adding the periods to the latest well observed maxima. The results are given in H. C. 197 and 202, and similar results are given for 1919 in Table I. The successive columns give the designation of the variable in hours and minutes of right ascension and degrees of declination, its designation according to the notation of Argelander, and the date of the predicted maximum. Stars south of declination -25° are here included for the first time, by the active aid of several southern observers.

TABLE I.

PREDICTED MAXIMA.

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1919.			1919.			1919.
001032	S Sculptoris	Feb. 4	010630	U Sculptoris	Apr. 19	022000	R Ceti	Mar. 12
001046	X Androm.	" 2	010940	U Androm.	Sept. 12	" "	" "	Aug. 24
001726	T "	Aug. 7	011041	UZ "	Oct. 8	022150	RR Persei	Dec. 2
001755	T Cassiop.	Nov. 19	011208	S Piscium	Apr. 25	022813	U Ceti	Jan. 22
001838	R Androm.	Oct. 26	011272	S Cassiop.	No Max.	" "	" "	Sept. 17
001909	S Ceti	June 6	011712	U Piscium	May 31	023080	RR Cephei	Apr. 14
002438a	T Sculptoris	Feb. 3	" "	" "	Nov. 22	023133	R Trianguli	Feb. 24
" "	" "	Aug. 27	012350	RZ Persei	May 20	" "	" "	Nov. 18
002546	T Phoenicis	Sept. 18	012502	R Piscium	Sept. 14	025751	T Horologii	Jan. 0
003179	Y Cephei	Aug. 9	013238	RU Androm.	Jan. 7	" "	" "	Aug. 3
004047	U Cassiop.	" 9	" "	" "	Sept. 2	030514	U Arietis	Apr. 21
004132	RW Androm.	Feb. 2	013338	Y "	May 29	031401	X Ceti	Apr. 4
004435	V "	May 29	014958	X Cassiop.	Dec. 22	" "	" "	Sept. 26
004533	RR "	June 3	015354	U Persei	July 4	032043	Y Persei	Feb. 2
004746	RV Cassiop.	May 25	015912	S Arietis	May 31	" "	" "	Oct. 12
004958	W "	Dec. 1	021024	R "	Apr. 21	032335	R "	Mar. 30
005475	U Tucanae	Jan. 9	" "	" "	Oct. 24	" "	" "	Oct. 26
" "	" "	Sept. 24	021143a	W Androm.	June 25	034625	U Eridani	Jan. 10
010102	Z Ceti	Apr. 12	021281	Z Cephei	Mar. 28	" "	" "	Sept. 6
" "	" "	Oct. 15	021403	o Ceti	Aug. 7	035124	T "	June 30

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1919.			1919.			1919.
042209	R Tauri	Feb. 15	065111	Y Monoc.	Aug. 26	094211	R Leonis	Apr. 27
042215	W "	Feb. 28	065208	X "	Mar. 31	094953	Z Velorum	Jan. 0
"	"	Nov. 24	"	"	Aug. 31	095421	V Leonis	Sept. 4
042309	S "	Apr. 11	065355	R Lyncis	Apr. 28	100661	S Carinae	Apr. 17
043065	T Camelop.	" 9	070109	V Can. Min.	Oct. 6	"	"	Sept. 12
043208	RX Tauri	Sept. 18	070122a	R Gemin.	" 22	101153	W Velorum	Apr. 21
043263	R Reticuli	Jan. 18	070310	R Can. Min.	May 21	103270	RZ Carinae	May 8
"	"	Oct. 24	070772	R Volantis	Dec. 10	103769	R. Urs. Maj.	Apr. 6
043274	X Camelop.	May 9	071044	L ² Puppis	Jan. 31	104814	W Leonis	No Max.
"	"	Sept. 28	"	"	June 20	110506	S Leonis	Feb. 10
043738	R Caeli	Dec. 18	"	"	Nov. 7	"	"	Aug. 19
044617	V Tauri	Mar. 17	071201	RR Monoc.	June 12	111661	RS Centauri	Apr. 21
"	"	Sept. 3	071713	V Gemin.	" 21	"	"	Oct. 2
045307	R Orionis	June 6	072708	S Can. Min.	Sept. 4	114441	X Centauri	July 18
045514	R Leporis	" 10	072811	T "	Aug. 5	115919	R Comae	June 23
050003	V Orionis	Jan. 20	072820b	Z Puppis	Sept. 13	120012	SU Virginis	Feb. 22
"	"	Oct. 16	073173	S Volantis	Aug. 21	"	"	Sept. 16
050022	T Leporis	Jan. 16	073508	U Can. Min.	July 1	120905	T "	Jan. 15
050848	S Pictoris	May 28	073723	S Gemin.	Aug. 29	"	"	Dec. 25
050953	R Aurigae	Jan. 15	074241	W Puppis	Jan. 1	121418	R Corvi	Oct. 8
051247	T Pictoris	Mar. 2	"	"	May 1	122532	T Can. Ven.	July 30
"	"	Sept. 8	"	"	Aug. 29	122803	Y Virginis	Jan. 26
051533	T Columbae	May 29	"	"	Dec. 27	"	"	Sept. 3
052036	W Aurigae	" 11	074323	T Gemin.	Jan. 0	122854	U Centauri	May 31
052404	S Orionis	Apr. 7	"	"	Oct. 16	123160	T Urs. Maj.	Mar. 13
053068	S Camelop.	" 25	075612	U Puppis	Feb. 10	"	"	Nov. 24
053531	U Aurigae	No Max.	"	"	Dec. 27	123307	R Virginis	Mar. 30
054331	S Columbae	Feb. 7	081112	R Cancri	Apr. 16	"	"	Aug. 22
"	"	Dec. 31	081617	V "	Feb. 2	123459	RS Urs. Maj.	July 18
054615a	Z Tauri	July 6	"	"	Oct. 30	123961	S " "	Feb. 8
054615c	RU "	Sept. 28	082476	R Chameleon.	Nov. 17	"	"	Sept. 19
054629	R Columbae	Feb. 3	083019	U Cancri	Mar. 30	124204	RU Virginis	May 13
"	"	Dec. 23	083350	X Urs. Maj.	Apr. 5	124606	U "	Feb. 14
054920	U Orionis	Aug. 1	"	"	Dec. 15	"	"	Sept. 6
054974	V Camelop.	No Max.	084803	S Hydrae	July 6	130212	RV "	Feb. 15
055353	Z Aurigae	Apr. 5	085008	T "	Feb. 1	"	"	Sept. 13
"	"	July 26	"	"	Nov. 15	132202	V "	Jan. 13
"	"	Nov. 15	090024	S Pyxidis	May 15	"	"	Sept. 18
055686	R Octantis	June 26	"	"	Dec. 8	132422	R Hydrae	Dec. 31
060450	X Aurigae	Feb. 16	090425	W Cancri	Sept. 10	132706	S Virginis	Feb. 16
"	"	July 30	091868	RW Carinae	May 1	133273	T Urs. Min.	Feb. 24
061647	V "	Nov. 17	092551	Y Velorum	" 18	134236	RT Cent.	Sept. 4
061702	V Monoc.	Sept. 30	092962	R Carinae	Oct. 6	134440	R Can. Ven.	" 8
063159	U Lyncis	Feb. 8	093014	X Hydrae	May 12	134536	RX Cent.	May 30
063558	S "	May 4	093178	Y Draconis	Jan. 21	134677	T Apodis	Apr. 2
064030	X Gemin.	June 18	"	"	Dec. 7	135908	RR Virginis	Mar. 14
064707	W Monoc.	Aug. 29	093934	R Leo Min.	Feb. 20	"	"	Oct. 16
065111	Y "	Jan. 12	094023	RR Hydrae	Jan. 31	140113	Z Bootis	Feb. 24

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1910.			1910.			1910.
140113	Z Bootis	Dec. 7	160524	RX Scorpii	Dec. 1	180565	W Draconis	July 24
140512	Z Virginis	Mar. 11	160625	RU Herculis	Apr. 17	181103	RY Ophiuchi	Mar. 14
141567	U Urs. Min.	July 28	161122a	R Scorpii	June 22	"	"	Aug. 12
141954	S Bootis	July 30	161122b	S "	May 13	181136	W Lyrae	May 1
142205	RS Virginis	Apr. 29	"	"	Nov. 6	"	"	Nov. 12
142539	V Bootis	May 19	161138	W Cor. Bor.	Apr. 4	182133	RV Sagittar.	Feb. 10
142584	R Camelop.	June 2	"	"	Dec. 3	"	"	Dec. 19
143227	R Bootis	July 5	161607	W Ophiuchi	Aug. 9	182224	SV Herculis	Feb. 16
143417	V Librae	June 12	162112	V "	July 12	"	"	Oct. 12
144918	U Bootis	Mar. 6	162119	U Herculis	Nov. 25	182306	T Serpentis	May 1
"	"	Aug. 27	162319	Y Scorpii	June 24	183149	SV Draconis	Jan. 9
150018	RT Librae	June 20	162807	SS Herculis	Feb. 23	"	"	Sept. 24
150519	T Librae	May 8	"	"	June 5	183225	RZ Herculis	June 18
"	"	Dec. 31	"	"	Dec. 24	183308	X Ophiuchi	July 10
150605	Y "	Feb. 4	162815	T Ophiuchi	Mar. 12	184134	RY Lyrae	Aug. 28
"	"	Nov. 5	162816	S "	July 20	184243	RW "	Nov. 26
151520	S "	Mar. 18	163137	W Herculis	Apr. 14	185032	RX "	Jan. 0
"	"	Sept. 26	163266	R Draconis	Aug. 17	"	"	Sept. 4
151714	S Serpentis	Aug. 25	164319	RR Ophiuchi	May 31	185512	ST Sagittar.	Dec. 7
151731	S Cor. Bor.	Jan. 29	164715	S Herculis	Aug. 7	185634	Z Lyrae	June 26
151822	RS Librae	May 21	164844	RS Scorpii	Feb. 21	185737	RT "	Sept. 2
"	"	Dec. 27	165030	RR "	Jan. 31	190108	R Aquilae	Feb. 24
152714	RU "	Jan. 0	"	"	Nov. 7	190529a	V Lyrae	Apr. 13
"	"	Nov. 13	165202	SS Ophiuchi	Apr. 4	190818	RX Sagittar.	May 7
152849	R Normae	Dec. 28	"	"	Nov. 15	190925	S Lyrae	Nov. 25
153020	X Librae	Feb. 24	165631	RV Herculis	July 6	190933a	RS "	July 30
"	"	Aug. 10	165636	RT Scorpii	Sept. 11	190941	RU "	Nov. 5
153378	S Urs. Min.	Oct. 18	170215	R Ophiuchi	July 30	190967	U Draconis	May 29
153620	U Librae	June 22	170627	RT Herculis	Sept. 26	191007	W Aquilae	Jan. 1
153654	T Normae	Mar. 18	171401	Z Ophiuchi	Apr. 1	191017	T Sagittar.	" 11
154536	X Cor. Bor.	Feb. 12	171723	RS Herculis	May 5	191019	R "	July 8
"	"	Oct. 10	"	"	Dec. 9	191319	S "	Feb. 4
154615	R Serpentis	Apr. 1	172486	S Octantis	May 9	"	"	Sept. 26
154639	V Cor. Bor.	Dec. 11	172809	RU Ophiuchi	Feb. 16	191321	Z "	June 23
154715	R Librae	June 18	"	"	Sept. 4	191637	U Lyrae	Jan. 18
154736	R Lupi	Jan. 23	174135	SV Scorpii	Aug. 21	192928	TY Cygni	Feb. 13
"	"	Sept. 12	174162	W Pavonis	Feb. 3	193311	RT Aquilae	" 1
155018	RR Librae	June 30	"	"	Nov. 11	"	"	Dec. 26
155229	Z Cor. Bor.	Jan. 1	174551	U Arae	Apr. 5	193449	R Cygni	No Max.
"	"	Sept. 8	175111	RT Ophiuchi	Aug. 17	193509	RV Aquilae	Apr. 26
155823	RZ Scorpii	Mar. 27	175458a	T Draconis	Mar. 27	"	"	Dec. 2
"	"	Sept. 3	175519	RY Herculis	Jan. 9	193972	T Pavonis	May 21
160031	Z "	Jan. 29	"	"	Aug. 17	194048	RT Cygni	Jan. 1
160118	R Herculis	Aug. 29	175654	V Draconis	" 27	"	"	July 7
160210	U Serpentis	May 27	180363	R Pavonis	Feb. 10	194348	TU "	" 15
160221a	X Scorpii	June 26	"	"	Sept. 28	194604	X Aquilae	Apr. 6
160519	W "	June 14	180531	T Herculis	Mar. 25	194632	x Cygni	May 23
160524	RX "	Apr. 3	"	"	Sept. 5	194929	RR Sagittar.	May 6

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1919.			1919.			1919.
195142	RU Sagittar.	Feb. 12	204016	T Delphini	Apr. 12	221230	R Pisc. Aust.	Apr. 15
"	"	Oct. 12	204104	W Aquarii	" 21	221321	X Aquarii	May 6
195202	RR Aquilae	Mar. 7	204318	V Delphini	No Max.	221938	T Gruis	Feb. 16
195308	RS	" 20	204405	T Aquarii	Jan. 21	"	"	July 4
195849	Z Cygni	July 20	"	"	Aug. 11	"	"	Nov. 19
200212	SY Aquilae	Apr. 11	204954	S Indi	Sept. 16	221948	S	July 30
200357	S Cygni	July 22	205017	X Delphini	June 22	222439	S Lacertae	Jan. 19
200514	R Capric.	June 20	205030a	UX Cygni	Dec. 31	"	"	June 9
200715a	S Aquilae	Feb. 25	205923	R Vulpec.	Apr. 27	223462	T Tucanae	" 28
"	"	July 25	"	"	Sept. 11	223841	R Lacertae	Mar. 2
"	"	Dec. 22	210124	V Capric.	Apr. 19	"	"	Dec. 27
200812	RU	June 21	"	"	Sept. 24	225120	S Aquarii	Sept. 8
200822	W Capric.	Feb. 16	210129	TW Cygni	Apr. 21	225914	RW Pegasi	June 30
"	"	Sept. 10	210221	X Capric.	Jan. 19	230110	R	Feb. 10
200906	Z Aquilae	Feb. 8	"	"	Aug. 25	230759	V Cassiop.	Aug. 7
"	"	June 16	210382	X Cephei	No Max.	231425	W Pegasi	Mar. 17
"	"	Oct. 22	210504	RS Aquarii	Jan. 1	231508	S	Jan. 31
201008	R Delphini	June 3	"	"	Aug. 9	"	"	Dec. 17
201130	SX Cygni	Dec. 13	210516	Z Capric.	" 13	232746	V Phoenicis	Mar. 29
201139	RT Sagittar.	July 21	210812	R Equulei	May 3	"	"	Dec. 9
201437b	WX Cygni	June 1	210868	T Cephei	Feb. 16	233335	ST Androm.	Jan. 21
"	"	Dec. 5	210903	RR Aquarii	Apr. 6	"	"	Nov. 27
201647	U	Oct. 20	"	"	Oct. 8	233815	R Aquarii	" 22
202240	U Microsc.	July 18	211614	X Pegasi	July 16	233956	Z Cassiop.	Mar. 30
202622	RU Capric.	Sept. 2	211615	T Capric.	Mar. 2	235053	RR	Sept. 8
202817	Z Delphini	Jan. 7	"	"	Nov. 27	235150	R Phoenicis	Mar. 1
"	"	Nov. 9	212030	S Microsc.	May 7	"	"	Nov. 25
202954	ST Cygni	June 15	"	"	Nov. 29	235209	V Ceti	June 20
203429	R Microsc.	Jan. 0	213678	S Cephei	Jan. 11	235265	R Tucanae	Feb. 5
"	"	May 19	214024	RR Pegasi	Mar. 27	"	"	Nov. 7
"	"	Oct. 5	"	"	Dec. 9	235350	R Cassiop.	May 16
203611	Y Delphini	Aug. 15	214247	R Gruis	Mar. 11	235525	Z Pegasi	Aug. 9
203816	S	Mar. 24	215605	V Pegasi	July 6	235715	W Ceti	July 18
"	"	Dec. 31	220412	T	June 22	235855	Y Cassiop.	Dec. 11
203847	V Cygni	May 14	220613	Y	" 14	235939	SV Androm.	Feb. 8
203905	Y Aquarii	June 10	220714	RS	Apr. 9	"	"	Dec. 23

The average deviation of the observed from the predicted maxima for 1917 is ± 12.6 days; for 1918, it is ± 11.4 days. The corresponding probable error is about nine days.

EDWARD C. PICKERING.

NOVEMBER 6, 1918.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 213.

PUBLICATIONS ISSUED IN 1918.

The principal publications of the Harvard College Observatory are its Annals, a series of quarto volumes of about two hundred and fifty pages each, and now numbering nearly a hundred. They are usually of a technical character and not of interest to the general public. It is believed, however, that the Observatory has many friends who will be interested in its progress, and will like to know of the substance of its publications. A summary is accordingly given below of the Annals issued during the year 1918. Also, of its briefer publications, called Circulars.

H.A. 79, Part 1. Leon Campbell. pp. 1-86. Observations of 323 variable stars, during the years 1911-1916. Previous results of a similar nature were published in H.A. 37, 57, and 63. The observations in H.A. 79, Part 1, have been made by about fifty observers, in general amateurs, belonging to the Variable Star Section of the British Astronomical Association and the American Association of Variable Star Observers, working with small telescopes. Their results have been supplemented, especially when the variables were faint, by observations made with large telescopes at the Amherst, Goodsell, and Harvard Observatories.

H.A. 80, No. 10. Edward S. King. pp. 153-190. 1 Plate. Eclipses of Jupiter's Satellites from photographic observations. All the plates were made with the 11-inch Draper Telescope. Visual observations of the times of these eclipses have been carried on at the Harvard Observatory for many years on a plan devised by the present Director, in 1878. These observations to 1903 are given in H.A. 52, Part 1, and a discussion of them by Professor R. A. Sampson is contained in H.A. 52, Part 2. The average difference between the times of eclipse found in H.A. 52, and those in H.A. 80, No. 10 is $\pm 20^{\circ}$. The photographic results for Satellites III and IV present larger discrepancies which are not readily explained.

H.A. 80, No. 11. Henry Norris Russell, assisted by Misses Fowler, Borton, and Fuller. pp. 191-219. Photographic determinations of the posi-

tion of the Moon, giving results derived from photographs taken with the 16-inch Metcalf Telescope between July 22, 1913 and December 29, 1916. This work is a continuation of that given in H.A. 72, No. 1, and H.A. 76, No. 7. The probable errors for a single plate are $\pm 0^s.050$ in right ascension and $\pm 0''.73$ in declination. The error in declination is slightly larger than that for the earlier series. This is apparently due to the grating, attached for determining absolute magnitudes.

H.A. 80, No. 12. C. A. Chant. pp. 221-229. The Light Curve of W Virginis. This variable star was discovered by Schönfeld in 1866 who determined a period of $17^d.2735$. The present investigation was based on an examination of 584 Harvard photographs, from which a period of $17^d.2711$ was derived.

H.A. 80, No. 13. Edward C. Pickering. pp. 231-256. Magnitudes of the Cape Photographic Durchmusterung. A discussion of the magnitudes in the Cape Photographic Durchmusterung for the first six hours of right ascension will be found in H.A. 76, No. 12. Three investigations are undertaken in the present paper. First, a comparison of the Cape magnitudes with the magnitudes on the International Scale of the stars in the Sequences of Harvard Standard Regions, given in H.A. 71, No. 4. Secondly, a special determination of the magnitudes of certain faint stars in these same regions. Thirdly, an extension of the investigation contained in H.A. 76, No. 12, to the later hours of right ascension. The magnitudes of the Cape Photographic Durchmusterung may be reduced to the International Scale by the application of two corrections, tables for which are given. Magnitudes on the International Scale are thus furnished for 454,875 southern stars.

H.A. 83, Part 2. Alexander McAdie. pp. 61-92. Observations and Investigations made at the Blue Hill Meteorological Observatory in the year 1917. In addition to the regular observations made twice daily, and the monthly and yearly means, the annual results for 32 years are given.

H.A. 84, No. 3. Genevieve F. (Matthews) Hubbard and Susan Raymond. pp. 57-84. Photographic Observations of Six Circumpolar Variables. This investigation has been carried on by the Maria Mitchell Fellows, and forms a continuation of H.A. 84, No. 1.

H.A. 91. Annie J. Cannon and Edward C. Pickering. The Henry Draper Catalogue, 0^h , 1^h , 2^h , and 3^h , pp. 1-290. 1 Plate. This is the first of nine volumes forming the Henry Draper Catalogue, which gives the class of spectrum, the photometric magnitude, and the photographic magnitude of about two hundred and twenty thousand stars. The classification was made by Miss Can-

non, and the reduction of the work was done by her or under her supervision. She was aided, on the average, by five assistants. The classification was begun in October, 1911, and completed in September, 1915. H.A. 92, containing 4^h, 5^h, and 6^h, is now being bound. H.A. 93, containing 7^h and 8^h, is in type. The copy for the remaining six volumes is practically ready for the printer. The best evidence of the demand for this work is that twenty-one thousand of these spectra have been furnished, in advance of publication, at the request of European astronomers from six different countries. Fifteen thousand spectra have also been sent to eight American astronomers.

Circular 203. Edward C. Pickering. Asteroids Bright in 1918. January 9, 1918. Positions are given of all these objects which are brighter than the tenth magnitude.

Circular 204. Leon Campbell. Nova Persei, No. 2. 032443. December 18, 1917. Observations of this object in 1902-17, and faint comparison stars. This is a continuation of H.A. 48, No. 2.

Circular 205. W. H. Pickering. The Distance of the Great Nebula in Orion. December 19, 1917. The distance found is 2000 parsecs.

Circular 206. W. H. Pickering. The Distance of the Pleiades and Coma Berenices. March 5, 1918. The distances found are 201 and 301 parsecs, respectively.

Circular 207. Henrietta S. Leavitt. A New Variable Star of Short Period. +37° 4717, H. V. 3435. June 10, 1918. This is a variable of Class IV, discovered by Miss Ashall, and having a period of 0^d.16. Its period increased suddenly in 1913, by 0^d.17.

Circular 208. Edward C. Pickering. The New Star, 184300, Nova Aquilae, No. 3. 1 plate, showing chart of region and light curve. July 23, 1918.

Circular 209. Annie J. Cannon. The spectrum of Nova Monocerotis, 072106. September 17, 1918. This star was photographed a few days after its outburst, but was not discovered for nearly two months. It had then faded from the fifth to the ninth magnitude. The spectrum had at that time reached the nebular stage. The two brightest lines were H α and 4363.

Circular 210. Edward C. Pickering. Illustrations of Nova Aquilae, No. 3. 184300. September 17, 1918. 1 plate, showing the star on May 22, 1888, and on June 3, 7, and 8, 1918.

Circular 211. Solon I. Bailey. Globular Clusters. October 31, 1918. The number of photographs available, and of those needed, for studying the variables in globular clusters.

Circular 212. Leon Campbell. Maxima in 1919 of Variable Stars of Long Period. November 6, 1918. Dates of maxima of 342 variables are predicted. The average difference, in 1918, between such predicted and observed maxima was 11.4 days.

Besides these, 30 Bulletins making 676, in all, the Seventy-Second Annual Report of the Director, and numerous minor publications have been issued.

EDWARD C. PICKERING.

JANUARY 1, 1919.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 214.

ASTRONOMICAL FELLOWSHIPS FOR WOMEN.

THE collection of stellar photographs of the Harvard College Observatory furnishes a fruitful field of study in many departments of Astronomy. Such work can be carried on to great advantage by women, especially as compared with visual work on the stars. It is independent of the weather and can be done in the daytime, at any convenient place, no matter where the original photographs were taken. Mrs. Fleming, Miss Cannon, Miss Leavitt and several other women have already availed themselves of these advantages with results which now fill numerous volumes of the Annals. It was pointed out in a "Statement of Proposed Astronomical Fellowships" that an opportunity was thus offered to women to undertake researches of much importance, if a moderate sum could be provided. Three Fellowships have accordingly been endowed:—The Astronomical Fellowship supported by the Nantucket Maria Mitchell Association; The Charles S. Hinchman Fellowship established in memory of the late Charles S. Hinchman; The Edward C. Pickering Fellowship contributed by many friends of the Observatory on the occasion of the fortieth anniversary of my appointment as Director.

The preceding portion of this circular was written by Professor Pickering a few days before his fatal illness. It has been completed according to his ideas, so far as possible.

The Astronomical Fellowship of the Nantucket Maria Mitchell Association was held from 1912 to 1916 by Miss Margaret Harwood, A.B. Radcliffe College, 1907, A.M. University of California, 1916. This fellowship was changed in 1916 to a permanent Directorship of the Nantucket Observatory, and Miss Harwood was appointed to the position. Her principal investigation at the Harvard Observatory has been upon the light curve of Eros. The results thus far indicate an almost continuous variation and a probable change in the period. Her study of the periods of the two eclipsing variable stars, Y Camelopardalis and TT Lyrae, is published in H.A. 84, No. 2 and her discovery of two new variable stars was announced in H.C. 194.

The Charles S. Hinchman Fellowship, originally called The Maria Mitchell Memorial Fellowship at Harvard Observatory, was offered for five years, from 1914 to 1919, by the joint gift of Professor E. C. Pickering and Mr. C. S. Hinchman. At Professor Pickering's suggestion, in April, 1918, the name was changed, in memory of the interest Mr. Hinchman displayed in all of these fellowships. Mrs. Hinchman then became responsible for the total amount of the fellowship, \$500.00, for the year 1919-20. This fellowship has been held by the following:—Miss Genevieve F. Mathews, A.B. Radcliffe College, 1912; Miss Susan Raymond, A.B. Smith College, 1913; Miss Dorothy W. Block, A.B. Hunter College, 1915, A.M. Columbia University, 1918; and Miss Mary D. Applegate, A.B. Vassar College, 1918. The principal work of these Fellows has been the measurement of the photographic magnitudes of stars and asteroids under the direction of Miss H. S. Leavitt. The observations of variable stars by Miss Mathews and Miss Raymond are printed in H.A. 84, Nos. 1 and 3. Miss Raymond's discovery of the variability of the star B.D. $+18^{\circ} 3186$ was announced in H.C. 201, and of the asteroid Antigone (129), in H.B. 633. Miss Block has measured the intensity of the bright lines in the spectra of the variable stars, α Ceti and R Hydrae. Miss Applegate, the Fellow for the present year, is engaged upon measures of variable stars in the region covered by plates of Harvard Map 2, and has discovered the variability of the star at R.A. $7^h 0^m.9$, Dec. $-75^{\circ} 50'$.

The Edward C. Pickering Fellowship was first held by Miss Mary H. Vann, A.B. 1912, Cornell University, and Miss D. W. Block is the Fellow for the current year. Miss Vann has measured the light of eleven new stars, shown on the Harvard photographs. As several of these stars were never observed visually, and were not photographed elsewhere, their light curves are of especial value. This work is ready for the printer and will be published as H.A. 84, No. 5.

Volume 84 of the Harvard Annals has been reserved for the work connected with these fellowships. Three numbers have been published, and No. 4 has been sent to the printer. It is a discussion of the photographic light curves of the circumpolar variable stars measured by these Fellows.

Applications for the Charles S. Hinchman and Edward C. Pickering Fellowships, each yielding \$500.00, for the year 1919-20, will now be received.

ANNIE J. CANNON.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 215.

PERTURBATION OF NEPTUNE.

THE attention of those astronomers who are interested in planetary orbits is called to the fact that Neptune has recently begun to deviate from the place that it should occupy in accordance with Newcomb's elements, and is now gradually falling behind its computed position, in the manner that it should do if perturbed by an unknown outer body. This was foreseen, but not expected prior to 1924. H.A. 61, 160. According to Professor Russell's measures of the Harvard plates, the deviation so far observed amounts to a little over 2". It is expected in the course of a few decades to increase to about 15". The deviation is slight, because the unknown planet is believed to be both small and remote. It is thought to be of terrestrial size, to be travelling in a highly elliptical orbit, and that its present annual parallax is 50', corresponding to a distance of 68 astronomical units. At its next opposition, December 30, 1919, it should be located in α 6^h 35^m, δ + 23°, magnitude 15. A brief memoir dealing with the elements of its orbit has been prepared, and is now in press. It is hoped that it will be possible to print and distribute it before the end of the present year.

The planet will be difficult to identify, not only on account of its faintness, but also because it is surrounded at present by countless stars in the Milky Way several magnitudes brighter than itself. The object in calling attention to it now, however, is not to ask aid in its discovery, although that will be gladly accepted, but rather to secure as many independent observations of the location of Neptune as possible, for determining its perturbation. These will be of value in determining the mass of the unknown body, in case it is not accompanied by a satellite. Although it may have a companion, this seems *à priori* improbable, and if it does not, so good an opportunity to determine its mass, as the next few years afford, will not occur again for a long time. The next favorable occasion will be after the next conjunction

with Uranus, some 40 years hence, but another conjunction with Neptune will not occur for three centuries.

These observations can probably best be made by means of photography, and at the same time would serve for a redetermination of the annual parallax of Neptune, which, as Newcomb pointed out, appeared in his time to be rather larger than his theory required. Astron. Papers of the Amer. Ephemeris, 7. The mean excess he found to be $+0''.22$. This he attributed to systematic errors varying with the hour of the night. We should expect that the sign of the deviation would now be reversed.

WILLIAM H. PICKERING.

MAY 1, 1919.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 216.

VARIABLE STARS IN THE CLUSTER, N. G. C. 3201.

IN Harvard Circular 211, it was announced that several variables had been discovered in N. G. C. 3201. This object is a very open cluster of fairly faint stars, with no condensed centre. A small photograph of this cluster is given in H.A. 60, No. 8, Plate 1.

A provisional Catalogue of Globular Clusters was given by Professor Bailey in H.A. 76, No. 4. Among these, a considerable number of objects were designated by the letter I, which indicated especially interesting clusters not already studied for variable stars. These objects, so far as they are covered by the Harvard plates, have been examined by the writer. N. G. C. 3201 proved to be one of the most interesting. A comparison of four plates of this cluster, taken with the 13-inch Boyden Telescope at Arequipa, was first made in 1916, and a large portion of the variables given below were found at that time. A few have been added since, but, as no further photographs are now available, it seems advisable to give the positions of those already found. With additional plates, the number of variables may be considerably increased. It is hoped that a sufficient number of photographs may be obtained soon to complete the examination for variables and to determine the periods and light curves of all.

N. G. C. 3201 is of special interest, not only on account of the large proportion of variable stars which it contains, but also from the fact that it is so open a cluster that practically all of the stars are well separated even at the centre.

No definite determination of magnitudes can be made with the material at present available, but, since the exposure required with the 13-inch Telescope is about that used for the discussion of Messier 3 and 5, it is probable that the variables range in general between the fourteenth and sixteenth magnitudes.

The position of the assumed centre, determined from the catalogue stars, is $10^h 13^m.5$, $-45^\circ 54'$ (1900). At this assumed centre is a bright star, the central one of three close stars. Within a radius of eight minutes of the centre, 527 stars were counted. Of these, 51 are variables, and 5 other variables are marked outside this limit. Several stars are also suspected and will be examined on plates that may be taken later. Variable No. 56 was discovered by Professor Bailey, while confirming the change in the other stars.

The measures were made on an enlargement, the scale of which was five seconds to the millimetre. Three of the catalogue stars and four variables lie outside the field of this enlargement. These were measured on one of the original plates, and are indicated in the fifth column of Table I by the letter R. A correction has been applied for orientation of the enlargement.

The positions of the new variable stars are given in Table I. The first column contains the designations. Capital letters indicate stars used for standards of position; small letters, a provisional sequence of comparison stars for estimating the magnitudes of the variables; and numerals, an adopted notation for the variables. A probable new nebula is indicated by Neb. The second column gives the zone and number for stars which are contained in the Cape Photographic Durchmusterung. The third and fourth columns give the coordinates, in seconds of arc, of each star from the centre of the cluster.

TABLE I.

FIFTY-SIX VARIABLE STARS IN N. G. C. 3201.

Des.	Cat. No.	x	y		Des.	Cat. No.	x	y	
A	$-45^\circ 4532$	-144	$+749$	R	k	.. ..	$+ 51$	-230	..
B	$-45^\circ 4528$	-431	$+298$	R	l	.. ..	$+ 32$	-270	..
C	$-45^\circ 4545$	$+467$	$+ 7$	..	m	.. ..	$- 50$	-156	..
D	$-45^\circ 4543$	$+315$	-495	..	n	.. ..	$+222$	-247	..
E	$-45^\circ 4527$	-449	$+293$	R	o	.. ..	$+ 18$	-250	..
a	.. ..	$+ 94$	$+511$	..	p	.. ..	$+ 33$	-218	..
b	.. ..	$- 38$	$+319$	..	q	.. ..	$- 7$	-206	..
c	.. ..	-338	$+166$	..	r	.. ..	$+107$	-250	..
d	.. ..	$- 58$	-263	..	s	.. ..	$- 3$	$+176$	..
e	.. ..	$+ 57$	-155	..	t	.. ..	-109	$+134$	..
f	.. ..	-321	$+239$	..	u	.. ..	$+ 85$	-209	..
g	.. ..	$- 40$	-269	..	w	.. ..	$- 66$	$+212$	..
h	.. ..	-207	$+204$	..	x	.. ..	$+ 81$	-203	..

Des.	Cat. No.	z	v		Des.	Cat. No.	z	v	
y		+ 20	-228	..	29	.. ..	-256	+113	..
z		+ 10	-132	..	30	.. ..	-289	+272	..
1		+ 59	-118	..	31	.. ..	+182	+131	..
2		+ 29	-117	..	32	.. ..	+195	+199	..
3		+182	- 43	..	33	.. ..	+ 48	- 40	..
4		+155	+ 3	..	34	.. ..	+296	+285	..
5		+ 42	- 24	..	35	.. ..	- 11	+121	..
6		-116	-143	..	36	.. ..	-108	- 11	..
7		- 91	-189	..	37	.. ..	- 68	- 74	..
8		- 69	- 99	..	38	.. ..	- 61	- 60	..
9		- 51	- 91	..	39	.. ..	+ 41	+ 54	..
10		-181	+235	..	40	.. ..	- 96	+ 68	..
11		-104	+112	..	41	.. ..	+291	+ 28	..
12		- 86	+108	..	42	.. ..	-301	+197	..
13		-160	+ 92	..	43	.. ..	-377	+ 15	..
14		-156	+133	..	44	.. ..	+ 31	+ 67	..
15		-279	-173	..	45	.. ..	+127	- 32	..
16		-197	-238	..	46	.. ..	-396	-510	..
17		+ 11	- 25	..	47	.. ..	+108	+245	..
18		+ 23	- 24	..	48	.. ..	-252	+ 12	..
19		+ 23	+317	..	49	.. ..	- 38	+151	..
20		+ 39	+284	..	50	.. ..	- 13	+ 27	..
21		+ 94	+135	..	51	.. ..	-205	- 26	..
22		-100	- 56	..	52	.. ..	+ 14	-812	R
23		- 49	- 50	..	53	.. ..	-873	-758	R
24		-339	+ 17	..	54	.. ..	+671	-804	R
25		+ 93	+173	..	55	.. ..	-338	+767	R
26		+219	-140	..	56	.. ..	+246	+ 94	..
27		+ 58	-323	..	Neb.	.. ..	+196	+170	..
28		+ 66	- 48	..					

IDA E. WOODS.

MAY 24, 1919.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 217.

VARIABLE STARS IN THE CLUSTER, N. G. C. 6362.

THIS object is an open cluster, very similar in appearance to N. G. C. 3201, which is described in Harvard Circular 216. The stars are well separated at the centre. A curious coincidence is that within a circle having a radius of eight minutes 523 stars were counted, while in N. G. C. 3201 the number in the same area was 527. Fourteen variables, whose positions are given below, were found in this cluster in 1918. No. 15 was discovered by Professor Bailey, while confirming the variability of the other stars. The cluster has been examined on three plates, the only ones at present available that are sufficiently good for comparison. These were taken in Arequipa with the 13-inch Boyden Telescope. The position of the assumed centre, reduced from the coordinates of the catalogue stars, is $17^h 21^m.6$, $-66^\circ 58'$ (1900). This centre is coincident with Variable No. 1.

The measures have been made on an enlargement, the scale of which is five seconds to the millimetre. The designations are given in the first column of Table I. Capital letters indicate stars used for standards of position; small letters, a provisional sequence of comparison stars for estimating the magnitude of the variables; and numerals, an adopted notation for the variables. For the fainter stars, two sequences are given, n to r and n' to r' , on opposite sides of the cluster, for convenience in making estimates of magnitude. The second column gives the zone and number for stars which are contained in the Cape Photographic Durchmusterung. The third and fourth columns give the coordinates, in seconds of arc, of each star from the centre of the cluster. There is no important correction for orientation of the plate. In the fifth column, x indicates that the star was outside the field of the enlargement, and was measured on one of the original plates.

TABLE I.

FIFTEEN VARIABLE STARS IN N. G. C. 6362.

Des.	Cat. No.	x	y		Des.	Cat. No.	x	y	
A	-66° 3116	-521	+641	R	r	.. ..	- 6	+106	..
B	-67° 3328	-889	-836	R	n'	.. ..	+ 89	- 90	..
C	-67° 3333	- 26	-729	R	o'	.. ..	+ 79	- 81	..
D	-66° 3121	+740	- 91	R	p'	.. ..	+ 47	- 63	..
E	-66° 3118	+369	+186	..	q'	.. ..	+ 72	-102	..
F	-67° 3329	-616	-767	R	r'	.. ..	+ 92	- 95	..
a	.. ..	-124	-190	..	1	.. ..	00	00	..
b	.. ..	+ 35	+134	..	2	.. ..	- 29	-100	..
c	.. ..	+157	+252	..	3	.. ..	- 83	- 89	..
d	.. ..	- 78	+ 16	..	4	.. ..	- 79	- 88	..
e	.. ..	+ 40	- 98	..	5	.. ..	+ 81	- 14	..
f	.. ..	- 78	- 70	..	6	.. ..	+ 54	+175	..
g	.. ..	- 84	- 17	..	7	.. ..	+ 22	+104	..
h	.. ..	- 73	- 53	..	8	.. ..	-263	+108	..
k	.. ..	-123	+ 4	..	9	.. ..	-207	+138	..
l	.. ..	- 68	+112	..	10	.. ..	+186	+352	..
m	.. ..	- 33	+ 86	..	11	.. ..	- 28	+ 48	..
n	.. ..	- 68	+ 93	..	12	.. ..	-245	-104	..
o	.. ..	- 47	+153	..	13	.. ..	-234	-120	..
p	.. ..	- 80	+121	..	14	.. ..	+370	+ 28	..
q	.. ..	- 84	+136	..	15	.. ..	+ 51	+ 2	..

JUNE 24, 1919.

IDA E. WOODS.





HARVARD COLLEGE OBSERVATORY.

CIRCULAR 218.

10 NEW VARIABLE STARS IN HARVARD MAPS 25 AND 28.

In continuation of the search for new variable stars, Maps 25 and 28 have been examined. A summary of the results is given in Table I, in the same form as in previous circulars. The successive columns give the number of the plate in the Map of the Sky, the approximate right ascension and declination of the centre, the number of new variables discovered, the total number found, the proportion which is new, the whole number known, the probable number, the proportion of the probable number which was actually found, the probable number unknown, and the probable proportion unknown. To find the probable number given in the seventh column, it is assumed that the number of new variables found is to the total number found, as the number previously known is to the whole number in the region.

TABLE I.

NUMBER AND DISTRIBUTION OF THE VARIABLES.

No.	Region.	New Variables.	Total.	Proportion New.	All.	Probable No.	Proportion Found.	Probable No. Unknown.	Proportion Unknown.
25	6 ^h 0°	4	15	.27	29	34	.44	5	.15
28	12 ^h 0°	6	10	.60	19	32	.31	13	.41

The following known variables were found. In H.M. 25, W Orionis, S Orionis, T Orionis, BF Orionis, ST Tauri, Z Orionis, RS Orionis, V Monocerotis, T Monocerotis, W Geminorum, and X Monocerotis. In H.M. 28, SS Virginis, Y Virginis, R Virginis and U Virginis. The Minor Planet Massalia was also found on a photograph taken March 4, 1910.

Table II contains a list of the new variable stars. The form is the same as that of H.C. 162. Since the range is small for most of these stars, the variation has been confirmed, by Miss Carpenter or Miss Mackie, on photographs taken with the 8-inch Draper or the 24-inch Bruce Telescopes.

CIRCULAR 218.

TABLE II.

NEW VARIABLE STARS.

Designation.	II. V.	Constellation.	D.M.	R.A. 1900.	Dec. 1900.	Br.	Ft.	Range.	Class.	No. Pl.
				<i>h. m. s.</i>	<i>° ' "</i>					
053106	3508	Orion	+6° 971	5 31 6.3	+ 6 46.2	9.5	10.3	0.8	IV?	54
061606	3509	Monoceros	+6° 1208	6 16 3.9	+ 6 31.0	8.6	9.6	1.0	IV	30
062105	3510	Monoceros	....	6 21 40.6	+ 5 26.1	10.2	<11.3>	1.1	II?	30
064604	3511	Monoceros	+4° 1476	6 46 39.1	+ 4 53.0	8.7	9.4	0.7	III	40
112800	3512	Leo	....	11 28 46.4	+ 0 31.3	10.0	11.2	1.2	..	24
113311	3513	Leo	....	11 33 23.2	+11 6.7	10.5	11.2	0.7	..	13
114605	3514	Virgo	-4° 3155	11 46 43.6	- 5 12.3	9.8	10.6	0.8	..	26
115903	3515	Virgo	+3° 2593	11 59 28.8	+ 3 10.6	10.0	11.1	1.1	..	20
120300	3516	Virgo	+0° 2900	12 3 26.5	+ 0 4.7	9.9	10.7	0.8	..	16
121600	3517	Virgo	....	12 16 8.8	+ 0 55.2	10.2	11.0	0.8	..	28

REMARKS.

061606. The spectrum is of Class G5 and the period is short. | 113311. A trace of the spectrum is seen on several plates. It does not appear to be of Class A, but rather of Class K or M.
062105. The period is probably long.
064604. The spectrum is of Class Mc. The period is probably irregular. | 114605. The spectrum is of Class K2. The variation is suspected to be of the Algol type.

August 14, 1919.

ANNIE J. CANNON.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 219.

200317. NOVA SAGITTAE. H. V. 3518.

THE new star 200317, Nova Sagittae, appeared in November, 1913, as announced in Bulletin 691. The position is in R. A. = $20^h 3^m 4^s$, Dec. = $+17^\circ 24'.3$ (1900). It was discovered by Miss Mackie in the course of a systematic examination of photographs covering the Milky Way. Two plates taken November 22, 1913, show it near its maximum brightness, magn. 7.2. Fortunately, a plate taken on the preceding night shows it of the magnitude 10.0. It was then increasing in brightness, and the date of the outburst is thus definitely fixed. During the next six weeks, it was visible on plates taken with the 1-inch and $\frac{1}{2}$ -inch Telescopes, but later became too faint for observation with small instruments. Plates taken with the 16-inch Metcalf Telescope during the summer of 1914 show it as a fourteenth magnitude star. Since that time, it has not certainly appeared on any plate taken here. We have no photographs showing the spectrum. On the best early plates, and on those made at the present time, there is a star image of the magnitude 14.5 whose position is nearly the same as that of the Nova. The plates taken with the 16-inch Telescope in 1914 show the image of this faint star slightly elongated and bright at the following end. It is thus proved that the Nova follows the faint star by approximately $0^s.2$. On plates taken with the same instrument this year, exposure 60 minutes, the image of the faint star appears somewhat hazy. It is uncertain whether this is caused by the proximity of the Nova. It would be interesting to obtain a photograph with a powerful telescope which would make it possible to determine the exact position and present brightness of both objects.

A ledger of observations is given in Table I. The successive columns contain the date, the length of exposure, the Julian Day, followed by a letter designating the instrument, and the estimated magnitude on a provisional scale. The letters e, m, and q, in the third column, refer to the 1-inch Cooke, 16-inch Metcalf, and $\frac{1}{2}$ -inch Voigtländer Telescopes, respectively. When

the quantity in the last column is printed in Italics, it indicates that the star was not seen, and was fainter than the given magnitude. As it is usually impossible to observe the Nova unless it is brighter than the star on which it is nearly superposed, *14.5* is the minimum given in the last column, although several of the plates show much fainter stars. The object was looked for and not found on 1 plate in 1891, 2 in 1892, 1 in 1893, 1 in 1894, 1 in 1895, 4 in 1896, 4 in 1897, 2 in 1898, 3 in 1899, 4 in 1900, 1 in 1901, 1 in 1902, 1 in 1903, and 1 in 1911. All of these plates were taken with the 8-inch, 16-inch, and 24-inch Telescopes, and their limiting magnitudes vary from the thirteenth to the sixteenth. In addition, numerous plates taken with the 1-inch Cooke lens in every year from 1901 to the present time do not show it. Their average limiting magnitude is about the twelfth.

TABLE I.
OBSERVATIONS OF NOVA SAGITTAE.

Date.	Exp.	J. D.	Magn.	Date.	Exp.	J. D.	Magn.
<i>y. m. d.</i>	<i>m.</i>			<i>y. m. d.</i>	<i>m.</i>		
1913, 11, 1	64	20073e	<i>12.5</i>	1913, 12, 15	66	20117q	10.3
11, 7	72	20079e	<i>11.8</i>	12, 19	88	20121q	9.9
11, 21	64	20093q	10.0	12, 27	64	20129q	<i>10.0</i>
11, 22	68	20094e	7.2	1914, 6, 17	10	20301m	13.8
11, 22	57	20094q	7.1	6, 25	10	20309m	13.8
11, 25	84	20097e	8.0	9, 17	10	20393m	13.8
11, 26	59	20098q	8.2	9, 21	10	20397m	14.1
12, 3	69	20105e	8.8	1916, 10, 18	60	21155m	<i>14.5</i>
12, 5	77	20107e	9.0	1919, 8, 28	60	22199m	14.4?
12, 11	61	20113q	9.8				

It is to be regretted that we have no plate showing the spectrum of this star. Its sudden appearance, however, followed by a fading of brightness which was at first rapid and then more gradual, is in conformity with the typical light curve for novae.

HENRIETTA S. LEAVITT,
JOAN C. MACKIE.

SEPTEMBER 18, 1919.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 220.

MAXIMA IN 1920 OF VARIABLE STARS OF LONG PERIOD.

The time of maximum of the variables of long period can now be predicted with a fair degree of certainty, due to the continually increasing value of the observations which are contributed to this Observatory. Observations have been received during the past year from forty-nine observers in the United States, sixteen in Europe, three in Africa, two in South America, one in Australia, and one in Hawaii. Predictions for preceding years have been published in Circulars 197, 202, and 212. Similar data for 1920 are given below in Table I. The successive columns give the designation of the variable in hours and minutes of right ascension and degrees of declination, the name, and the computed date of maximum.

TABLE I.
PREDICTED MAXIMA.

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1920.			1920.			1920.
000339	V Sculptoris	Aug. 23	005475	U Tucanae	June 8	021281	Z Cephei	Nov. 13
001032	S "	Jan. 16	010103	Z Ceti	Apr. 19	021403	o Ceti	July 5
"	" "	Dec. 31	" "	" "	Oct. 24	022000	R "	Feb. 25
001046	X Androm.	Jan. 0	010630	U Sculptoris	Mar. 4	022150	RR Persei	Dec. 19
001726	T "	May 13	010940	U Androm.	Aug. 17	022813	U Ceti	Apr. 30
001755	T Cassiop.	No Max.	011041	UZ "	Sept. 2	" "	" "	Dec. 22
001838	R Androm.	Dec. 11	011208	S Piscium	June 4	022980	RR Cephei	May 4
001862	S Tucanae	Mar. 26	011272	S Cassiop.	May 5	023133	R Trianguli	Aug. 18
"	" "	Nov. 17	011712	U Piscium	" 5	025050	R Horologii	Apr. 25
001909	S Ceti	Apr. 30	" "	" "	Oct. 25	025751	T "	Mar. 4
002438a	T Sculptoris	Feb. 15	012350	RZ Persei	May 8	" "	" "	Oct. 8
"	" "	Sept. 2	012502	R Piscium	July 18	030514	U Arietis	May 25
002546	T Phoenicis	June 19	013238	RU Androm.	May 8	031401	X Ceti	Mar. 18
003179	Y Cephei	July 21	013338	Y "	Jan. 26	" "	" "	Sept. 10
004047	U Cassiop.	May 21	" "	" "	Sept. 2	032043	Y Persei	May 7
004132	RW Androm.	Apr. 7	014958	X Cassiop.	Dec. 31	" "	" "	Dec. 31
004435	V "	Feb. 25	015354	U Persei	May 15	032335	R "	June 5
004435	X Sculptoris	Jan. 19	015912	S Arietis	Apr. 9	" "	" "	Dec. 31
"	" "	Oct. 2	021024	R "	" 29	034625	U Eridani	May 15
004533	RR Androm.	May 5	" "	" "	Nov. 1	" "	" "	Dec. 31
004746a	RV Cassiop.	Apr. 19	021143a	W Androm.	Aug. 23	035124	T "	Mar. 26
004958	W "	Dec. 24	021281	Z Cephei	Feb. 2	" "	" "	Dec. 11

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1920.			1920.			1920.
040725	W Eridani	Dec. 9	065111	Y Monoc.	Apr. 8	094211	R Leonis	Dec. 31
042209	R Tauri	Nov. 5	"	"	Nov. 20	094953	Z Velorum	Mar. 26
042215	W "	July 26	065208	X "	Jan. 31	095421	V Leonis	June 4
042309	S "	Apr. 5	"	"	July 2	095563	RV Carinae	May 5
043065	T Camelop.	May 25	"	"	Dec. 2	100661	S "	Feb. 13
043208	RX Tauri	Aug. 18	065355	R Lynceis	May 23	"	"	July 11
043263	R Reticuli	June 29	070109	V Can. Min.	Oct. 10	"	"	Dec. 7
043274	X Camelop.	Feb. 17	070122a	R Gemin.	Nov. 21	101058	Z "	Sept. 8
"	"	July 9	070310	R Can. Min.	Feb. 5	101153	W Velorum	June 24
"	"	Nov. 29	071044	L ² Puppis	Mar. 26	103270	RZ Carinae	Feb. 15
043738	R Caeli	No Max.	"	"	Aug. 13	"	"	Nov. 11
044349	R Pictoris	Mar. 21	"	"	Dec. 31	103769	R Urs. Maj.	Jan. 31
"	"	Sept. 2	070772	R Volantis	Jan. 6	"	"	Nov. 26
044617	V Tauri	Feb. 25	071201	RR Monoc.	July 10	104814	W Leonis	Dec. 13
"	"	Aug. 13	071713	V Gemin.	Apr. 3	110506	S "	Feb. 25
045307	R Orionis	Dec. 1	"	"	Dec. 31	"	"	Sept. 2
045514	R Leporis	Aug. 3	072708	S Can. Min.	July 14	111661	RS Centauri	Mar. 14
050003	V Orionis	July 6	072811	T "	June 24	"	"	Aug. 25
050022	T Leporis	Feb. 5	072820b	Z Puppis	No Max.	114441	X "	May 21
050848	S Pictoris	July 21	073173	S Volantis	Oct. 2	115919	R Comae	" 27
050953	R Aurigae	May 13	073508	U Can. Min.	June 24	120012	SU Virginis	Apr. 13
051247	T Pictoris	Apr. 5	073723	S Gemin.	" 14	"	"	Nov. 4
"	"	Oct. 22	074241	W Puppis	Apr. 25	120905	T "	" 29
051533	T Columbae	Jan. 6	"	"	Aug. 23	121418	R Corvi	Dec. 1
"	"	Aug. 18	"	"	Dec. 21	122532	T Can. Ven.	Apr. 25
052036	W Aurigae	Feb. 10	074323	T Gemin.	Aug. 1	122803	Y Virginis	" 25
"	"	Nov. 11	075612	U Puppis	Nov. 1	"	"	Dec. 1
052404	S Orionis	Apr. 15	081112	R Cancr.	Mar. 28	122854	U Centauri	Aug. 3
053068	S Camelop.	Feb. 25	081617	V "	June 22	123160	T Urs. Maj.	" 4
053531	U Aurigae	Jan. 29	082476	R Chameleon.	Oct. 22	123307	R Virginis	Jan. 18
054331	S Columbae	Nov. 21	083019	U Cancr.	Jan. 1	"	"	June 11
054629	R "	" 11	"	"	Oct. 27	"	"	Nov. 3
054615a	Z Tauri	Oct. 2	083350	X Urs. Maj.	Aug. 3	123459	RS Urs. Maj.	Mar. 26
054615c	RU "	No Max.	084803	S Hydrae	Mar. 16	"	"	Dec. 11
054920	U Orionis	Aug. 3	"	"	Dec. 1	123961	S " "	May 20
054974	V Camelop.	Mar. 11	085008	T "	Aug. 21	"	"	Dec. 31
055353	Z Aurigae	Feb. 20	085120	T Cancr.	Nov. 15	124204	RU Virginis	July 26
"	"	June 9	090024	S Pyxidis	July 16	124606	U "	Mar. 24
"	"	Sept. 27	090425	W Cancr.	Sept. 30	"	"	Oct. 14
055686	R Octantis	July 26	091863	RW Carinae	Mar. 6	130212	RV "	Apr. 15
060450	X Aurigae	Jan. 1	092551	Y Velorum	Aug. 27	"	"	Nov. 11
"	"	June 4	092962	R Carinae	" 13	131283	U Octantis	July 9
"	"	Nov. 11	093014	X Hydrae	Feb. 28	132202	V Virginis	May 25
061647	V "	Sept. 22	"	"	Dec. 16	132422	R Hydrae	Nov. 21
061702	V Monoc.	Aug. 13	093178	Y Draconis	Jan. 6	132706	S Virginis	Feb. 1
063159	U Lynceis	Apr. 25	"	"	Nov. 21	133273	T Urs. Min.	Jan. 10
063558	S "	Feb. 15	093934	R Leo Min.	Feb. 15	"	"	Nov. 19
"	"	Dec. 11	094023	RR Hydrae	Jan. 6	133633	T Centauri	Jan. 11
064030	X Gemin.	Mar. 26	"	"	Dec. 8	"	"	Apr. 10
"	"	Dec. 21	094211	R Leonis	Feb. 29	"	"	July 9

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1920.			1920.			1920.
133633	T Centauri	Oct. 7	155229	Z Cor. Bor.	Jan. 1	172486	S Octantis	Oct. 17
134236	RT "	Apr. 25	"	" " "	Aug. 28	172809	RU Ophiuchi	Mar. 24
"	"	Dec. 31	155823	RZ ScorpII	Feb. 8	"	"	Oct. 10
134440	R Can. Ven.	July 9	"	" " "	July 15	173543	RU ScorpII	Dec. 15
134536	RX Centauri	Apr. 2	"	" " "	Dec. 20	174135	SV "	May 22
134677	T Apodis	Jan. 0	160020	Z "	Jan. 26	174162	W Pavonis	Aug. 19
"	"	Sept. 21	160118	R Herculis	" 9	174551	U Arae	June 12
135908	RR Virginis	June 9	160210	U Serpentis	" 26	175111	RT Ophiuchi	Oct. 2
140113	Z Bootis	Aug. 15	"	" " "	Sept. 22	175458a	T Draconis	Apr. 25
140512	Z Virginis	Jan. 6	160221a	X ScorpII	Jan. 1	175519	RY Herculis	" 3
"	"	Nov. 9	"	" " "	July 9	"	"	Nov. 9
140528	RU Hydrae	Aug. 27	160519	W "	Jan. 26	175654	V Draconis	May 30
140959	R Centauri	July 27	"	" " "	Sept. 7	180363	R Pavonis	" 13
141567	U Urs. Min.	June 16	160524	RX "	Mar. 11	"	"	Dec. 29
141954	S Bootis	May 5	160625	RU Herculis	July 2	180531	T Herculis	Feb. 25
142205	RS Virginis	Apr. 28	161122a	R ScorpII	Jan. 16	"	"	Aug. 7
142539	V Bootis	Feb. 21	"	" " "	Aug. 23	180565	W Draconis	Apr. 25
142584	R Camelop.	" 29	161122b	S "	May 4	180666	X "	" 20
143227	R Bootis	" 13	"	" " "	Oct. 28	"	"	Sept. 18
"	"	Sept. 23	161138	W Cor. Bor.	July 28	181103	RY Ophiuchi	Jan. 12
143417	V Librae	Feb. 20	161607	W Ophiuchi	" 4	"	"	June 11
"	"	Nov. 1	162112	V "	Mar. 26	"	"	Nov. 9
144918	U Bootis	Jan. 26	"	" " "	Dec. 31	181136	W Lyrae	May 25
"	"	July 22	162119	U Herculis	" 19	"	"	Dec. 6
145254	Y Lupi	Nov. 16	162319	Y ScorpII	June 23	182133	RV Sagittarii	Nov. 2
150018	RT Librae	Feb. 7	162807	SS Herculis	Jan. 11	182224	SV Herculis	June 14
"	"	Oct. 16	"	" " "	Apr. 25	182306	T Serpentis	Apr. 5
150519	T "	Jan. 4	"	" " "	Aug. 8	183149	SV Draconis	June 10
"	"	Aug. 29	"	" " "	Nov. 21	183225	RZ Herculis	May 5
150605	Y "	" 3	162815	T Ophiuchi	Mar. 6	183308	X Ophiuchi	" 20
151520	S "	Mar. 26	162816	S "	" 30	184134	RY Lyrae	Aug. 3
"	"	Oct. 2	163137	W Herculis	Jan. 16	184243	RW "	Feb. 20
151714	S Serpentis	Aug. 13	"	" " "	Oct. 20	185032	RX "	May 12
151731	S Cor. Bor.	Jan. 26	163266	R Draconis	Apr. 15	185512	ST Sagittarii	Dec. 31
151822	RS Librae	July 24	"	" " "	Dec. 16	185634	Z Lyrae	Apr. 21
152714	RU "	Sept. 26	164319	RR Ophiuchi	Mar. 16	185737	RT "	May 25
152849	R Normae	Jan. 16	164715	S Herculis	June 10	190108	R Aquilae	Nov. 6
153020	X Librae	" 6	164844	RS ScorpII	Jan. 10	190529	V Lyrae	Apr. 19
"	"	June 24	"	" " "	Nov. 28	190818	RX Sagittarii	" 4
"	"	Dec. 9	165030	RR "	July 29	190925	S Lyrae	No Max.
153378	S Urs. Min.	Sept. 2	165202	SS Ophiuchi	June 27	190933	RS "	May 15
153620	U Librae	Jan. 16	165631	RV Herculis	Jan. 31	190941	RU "	Nov. 19
"	"	Aug. 29	"	" " "	Aug. 20	190967	U Draconis	May 15
153654	T Normae	July 16	165636	RT ScorpII	Dec. 21	191007	W Aquilae	Apr. 15
154536	X Cor. Bor.	May 16	170215	R Ophiuchi	May 30	191017	T Sagittarii	Jan. 26
154615	R Serpentis	Apr. 3	170627	RT Herculis	" 25	191019	R "	Mar. 26
154639	V Cor. Bor.	Dec. 1	170833	RW ScorpII	Dec. 15	"	"	Dec. 16
154715	R Librae	July 24	171401	Z Ophiuchi	Mar. 6	191124	TY "	June 14
154736	R Lupi	Apr. 25	171723	RS Herculis	July 29	191319	S "	May 17
155018	RR Librae	" 5	172486	S Octantis	Jan. 31	191321	Z "	Sept. 17

Des.	Name.	Date.	Des.	Name.	Date.	Des.	Name.	Date.
		1920.			1920.			1920.
191331	SW Sagittarii	Apr. 15	202954	ST Cygni	June 6	215605	V Pegasi	Apr. 25
191637	U Lyrae	May 25	203429	R Microse.	Feb. 21	215828	S Pisc. Aust.	May 27
192928	TY Cygni	Jan. 14	"	"	July 9	215934	RT Pegasi	July 14
"	"	Dec. 19	"	"	Nov. 25	220412	T "	June 24
193311	RT Aquilae	Nov. 16	203611	Y Delphini	" 11	220613	Y "	Jan. 26
193449	R Cygni	Jan. 8	203816	S "	Oct. 2	"	"	Aug. 16
193509	RV Aquilae	July 9	203847	V Cygni	July 5	220714	RS "	June 18
193972	T Pavonis	Jan. 16	203905	Y Aquarii	June 4	221230	R Pisc. Aust.	Feb. 3
"	"	Sept. 22	204016	T Delphini	Mar. 16	"	"	Nov. 23
194048	RT Cygni	Jan. 12	204104	W Aquarii	May 5	221321	X Aquarii	Mar. 16
"	"	July 20	204215	U Capric.	" 25	221722	RT "	Apr. 8
194348	TU "	Feb. 15	204318	V Delphini	Mar. 16	"	"	Dec. 5
"	"	Sept. 17	204405	T Aquarii	Feb. 10	221938	T Gruis	Apr. 25
194604	X Aquilae	Mar. 11	"	"	Aug. 31	"	"	Sept. 12
194632	X Cygni	June 29	204846	RZ Cygni	Jan. 31	221948	S "	Aug. 23
194659	S Pavonis	Jan. 6	"	"	Oct. 30	222129	RV Pegasi	Nov. 9
194929	RR Sagittarii	Apr. 2	204954	S Indi	" 17	222439	S Lacertae	May 8
195142	RU "	" 30	205017	X Delphini	Apr. 5	"	"	Dec. 31
"	"	Dec. 16	205030	UX Cygni	Jan. 2	223462	T Tucanae	Feb. 19
195202	RR Aquilae	Apr. 5	205627	RR Capric.	Apr. 15	"	"	Oct. 27
195308	RS "	" 29	"	"	Dec. 31	223841	R Lacertae	June 6
195849	Z Cygni	May 7	205923	R Vulpeculae	Jan. 26	"	"	Nov. 1
200212	SY Aquilae	Apr. 5	"	"	June 11	225120	S Aquarii	June 19
200357	S Cygni	June 30	"	"	Oct. 26	225914	RW Pegasi	Jan. 26
200514	R Capric.	May 29	210124	V Capric.	Feb. 5	"	"	Aug. 22
200715a	S Aquilae	Jan. 1	"	"	July 11	230110	R "	Mar. 6
"	"	June 1	"	"	Dec. 15	230759	V Cassiop.	" 16
"	"	Oct. 31	210129	TW Cygni	Apr. 2	"	"	Nov. 3
200747	R Telescopii	Feb. 22	210221	X Capric.	Mar. 26	231425	W Pegasi	Mar. 1
200812	RU Aquilae	Mar. 14	"	"	Oct. 30	231508	S "	Oct. 20
"	"	Dec. 14	210382	X Cephei	May 25	232746	V Phoenicis	Aug. 16
200822	W Capric.	Apr. 5	210504	RS Aquarii	Mar. 6	233335	ST Androm.	Jan. 26
"	"	Oct. 30	"	"	Oct. 6	"	"	Nov. 21
200906	Z Aquilae	Feb. 12	210516	Z Capric.	Aug. 3	233815	R Aquarii	Dec. 31
"	"	June 18	210812	R Equulei	June 18	233956	Z Cassiop.	Aug. 3
"	"	Oct. 23	"	"	Oct. 2	235053	RR "	July 4
200938	RS Cygni	" 17	210868	T Cephei	Mar. 6	235150	R Phoenicis	" 14
201008	R Delphini	Mar. 6	210903	RR Aquarii	Apr. 10	235209	V Ceti	Mar. 6
"	"	Dec. 15	"	"	Oct. 17	"	"	Nov. 21
201130	SX Cygni	" 31	211614	X Pegasi	Feb. 10	235265	R Tucanae	Aug. 8
201139	RT Sagittarii	July 4	"	"	Sept. 1	235350	R Cassiop.	" 25
201437b	WX Cygni	May 30	211615	T Capric.	Aug. 22	235525	Z Pegasi	June 19
"	"	Nov. 21	212030	S Microsc.	July 4	235715	W Ceti	Apr. 9
201647	U "	No Max.	213678	S Cephei	Mar. 16	235855	Y Cassiop.	Dec. 31
202240	U Microsc.	May 18	214024	RR Pegasi	Aug. 17	235939	SV Androm.	Nov. 7
202622	RU Capric.	July 16	214247	R Gruis	Feb. 5			
202817	Z Delphini	Aug. 23	"	"	Dec. 31			

APP - 1920

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 221.

STARS HAVING COMPOSITE SPECTRA. 73 NEW DOUBLE STARS.

Professor Pickering published an article entitled "The Discovery of Double Stars by Means of their Spectra," in the *Astronomische Nachrichten*, 127, 157, under date of February 19, 1891. After describing composite spectra as being generally of a type resembling that of the Sun, except that the hydrogen lines are strong, he recommended the observation of these objects to detect close visual companions, or the measurement of the position of the hydrogen and other lines, for variable velocity in the line of sight.

A large number of composite spectra have been discovered in the course of the study of the photographs of the Henry Draper Memorial. Eighteen were found by Miss Maury and were published in H.A. 28, 93. Two hundred and sixty-one have been found by the writer, of which one hundred and forty-five have already been published in H.A. 28, 229, H.A. 56, 113, 160, H. C. 178, H. C. 184, and H. C. 196. The appearance of all of these spectra is that of two distinct classes superposed. When two close stars have similar spectra, the result on photographs of small dispersion consists only in a widening of the lines. These cases are not included in the lists of composite spectra.

Table I gives the additional list of stars having composite spectra. The first four columns contain the *Durchmusterung* zone and number, the right ascension for 1900, the declination for 1900, and the photometric or the reduced *Durchmusterung* magnitude, the latter being carried to tenths only. The fifth column gives the number in Burnham's "General Catalogue of Double Stars," or the hour and number in Innes' "Southern Double Stars," for stars contained in those works. The sixth and seventh columns give the class of the brighter and fainter components, as shown from the photographic spectrum. When the difference in brightness of the two components is about one magnitude, the visual order of brightness may be the reverse of the photographic. An example of such a case is the star $+35^{\circ} 3573$, R. A. $19^h 16^m.2$, Dec. $+35^{\circ} 21'$.

TABLE I.

STARS HAVING COMPOSITE SPECTRA. 73 NEW DOUBLE STARS.

DM.		R.A. 1900.		Dec. 1900.		Magn.	Des.	Brighter.	Fainter.
		<i>h.</i>	<i>m.</i>	<i>°</i>	<i>'</i>				
-73°	4	0	5.7	-73	47	6.76	0 ^h 7	A5	G
+27°	80		26.7	+27	58	8.6	265	G	A2
+48°	177		30.3	+48	29	7.00	317	A2	K
+69°	61		54.9	+70	0	7.84	....	F5	A5
+51°	239	1	4.0	+51	31	7.81	603	F5	A
+57°	320		27.0	+57	49	6.05	....	K0	A0
+21°	243		44.6	+21	47	5.89	963	F5	A2
+22°	329	2	13.3	+22	43	6.42	....	A5	G
+51°	599		29.9	+51	32	7.34	....	G5	A5
+43°	576		41.0	+43	50	6.74	....	F5	A
+56°	718		42.2	+56	40	6.53	....	F5	A2
-15°	493		42.4	-15	47	8.3	R	F5	A3
+ 6°	496	3	7.1	+ 6	18	5.84	....	G5	A5
+44°	732		25.5	+44	30	7.32	....	K0	A
+60°	768		48.6	+60	49	5.22	1927	K0	A0
+40°	1000	4	29.7	+41	4	4.46	....	K0	A3
-51°	1281		49.0	-51	53	6.62	4 ^h 59	F5	A2
+26°	787	5	0.9	+26	52	8.4	....	A	G
+ 8°	866		2.5	+ 8	22	5.47	2535	F0	A2
+ 1°	938		8.3	+ 1	51	6.25	2588	A2	G
+43°	1315		30.1	+44	1	7.42	....	F8	A0
+38°	1250		34.7	+38	8	8.0	....	A	G
-64°	486		50.8	-64	4	6.42	....	K0	A3
+12°	968		53.2	+12	48	5.77	3078	G5	A5
+59°	1028	6	44.2	+59	34	5.44	3625	F5	A2
+18°	1365		44.3	+18	54	7.7	....	F5	A3
-13°	1741		51.5	-13	55	5.19	3725	G5	A2
+ 2°	1483		52.7	+ 2	26	7.7	....	A2	G
+23°	1647	7	8.8	+23	16	7.8	....	K	A
- 4°	1862		8.8	- 4	59	7.50	....	A0	G5
-43°	3133		17.8	-43	38	9.0	7 ^h 31	A5	K
+ 8°	1791		25.6	+ 8	46	7.16	....	A2	G
- 8°	1961		27.1	- 8	28	9.1	4113	A	G
-18°	1893		27.8	-18	17	7.5	....	F0	A3
-56°	1437		46.2	-56	13	6.18	....	K0	A2
-45°	3591		53.7	-45	47	8.5	....	G0	A2
+ 4°	1945	8	12.1	+ 4	31	6.68	....	G0	A2
+25°	1920		20.7	+24	52	6.58	4602	A3	G
-23°	7316		22.5	-23	29	8.2	....	A2	K
+13°	1972		37.7	+13	3	5.67	....	A3	G
-63°	1126	9	24.6	-63	11	8.2	....	G0	A0

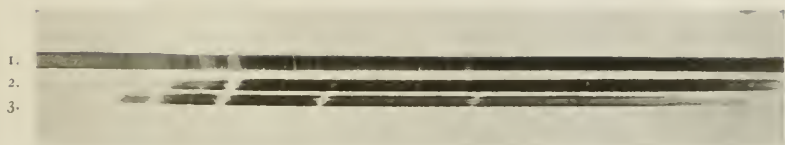
DM.	R.A. 1900.		Dec. 1900.	Magn.	Des.	Brighter.	Fainter.
	<i>h.</i>	<i>m.</i>	<i>°</i>				
-30° 7704	9	31.8	-30 47	7.9	9 ^h 50	A3	G
+69° 528		32.1	+69 0	8.1	....	F2	A2
-57° 2780	10	7.9	-57 33	8.4	....	G0	A
-47° 6042		33.1	-47 42	4.06	10 ^h 59	F2	A3
-58° 2460		34.9	-58 40	4.73	10 ^h 62	K5	A
-57° 4181	11	0.0	-57 56	8.6	....	K0	A2
+25° 2352		7.1	+25 11	8.3	....	F5	A5
+34° 2264		46.0	+33 56	6.14	....	F2	A2
-51° 6290		57.2	-51 58	7.0	....	F2	A5
-68° 1610		59.0	-68 58	7.1	....	G5	A2
+31° 2350	12	13.5	+30 49	6.14	....	F5	A2
-68° 1642		16.0	-68 33	7.5	....	G0	A0
-43° 7624		16.2	-43 42	7.6	....	G5	A3
+41° 2307		22.6	+41 55	6.85	....	F5	A3
+45° 2038		23.3	+45 21	6.91	6179	F5	K
-53° 5169		24.0	-53 24	8.4	....	G0	A2
+15° 2491		34.2	+14 54	7.99	6233	A3	G
-66° 1881		35.6	-66 25	8.7	....	F5	A3
-59° 4474		43.4	-60 7	8.11	....	K0	A
+19° 2613		47.0	+19 42	7.15	6289	F2	A2
-61° 3830	13	29.8	-61 50	7.3	....	G0	A3
-17° 3949		47.2	-18 13	7.02	....	F2	A2
-63° 3478	14	54.5	-63 17	8.4	....	K0	A5
-74° 1309		55.1	-74 12	8.6	....	K0	A3
-67° 2807	15	7.2	-67 7	8.6	....	F0	A0
+10° 2818		11.8	+10 4	6.64	....	A2	G
-50° 9676		32.1	-50 44	8.1	....	A3	G
-50° 9808		38.9	-50 36	8.7	....	F5	A0
+41° 2689	16	15.9	+41 53	7.86	7587	A5	G
-60° 6532		19.6	-60 54	8.8	....	F5	A2
-43° 11083		38.7	-43 27	8.1	....	K0	A0
+44° 2690	17	15.9	+44 14	9.0	7970	F2	A2
-17° 5055	18	5.3	-17 24	8.9	....	G5	A0
+16° 3390		5.7	+16 27	6.14	8398	F2	A0
-20° 5068		10.7	-20 34	7.07	....	G5	A5
-18° 4962		20.6	-18 9	8.1	....	A2	G0
-28° 14742		29.5	-28 54	9.0	8641	G	A
-18° 5070		42.1	-18 19	8.3	....	F2	A2
+49° 2871		45.0	+49 19	7.18	8849	A2	G
-17° 5350		45.8	-17 25	8.6	8853	F2	A2
+35° 3573	19	16.2	+35 21	7.82	9230	A0	K
+55° 2215		29.2	+55 31	6.52	....	K2	A3
+30° 3692		37.4	+30 29	7.16	9524	G5	A3
+26° 3654		39.8	+26 54	6.56	R	K0	A0
+10° 4034		40.1	+10 42	8.7	....	K0	A

DM.	R.A. 1900.		Dec. 1900.		Magn.	Dcs.	Brighter.	Fainter.
	<i>h.</i>	<i>m.</i>	<i>°</i>	<i>'</i>				
+23° 3760	19	41.2	+23	41	7.01	....	B8p	F5
- 3° 4742		48.1	- 3	22	5.64	....	Fop	A
+16° 4053		49.2	+16	31	7.61	....	G0	A2
+35° 3994	20	5.5	+35	11	7.17	9956	B3	G?
+13° 4332		10.8	+13	19	7.9	....	G0	A
+13° 4356		14.7	+14	4	6.81	10099	A0	G
+25° 4272		27.7	+25	28	6.29	10305	A2	G
+31° 4181		37.0	+31	57	5.77	10437	K0	A
+38° 4235		44.2	+38	55	7.01	....	F5	A3
+19° 4544		47.8	+19	45	7.22	10581	F5	A0
+58° 2187		51.3	+58	56	6.82	10618	F2	A2
- 6° 5664		58.7	- 6	13	5.63	10698	F5	A3
+51° 3079	21	28.1	+52	11	6.20	....	K0	A3
+50° 3416		39.7	+50	33	8.1	11217	G5	A2
+49° 3648		48.5	+49	20	9.3	....	K0	A0
+65° 1664		49.1	+65	17	6.41	11334	A2	G
+66° 1463		55.2	+66	39	9.0	11420	F5	A
+46° 3719	22	25.4	+47	11	4.61	....	K0	A0
+56° 2794		26.5	+56	43	6.73	11778	A2	G
+69° 1262		30.1	+69	24	6.02	11828	F2	A5
+68° 1319		34.3	+68	41	7.46	....	A3	G
-11° 5931		44.5	-11	36	9.2	11986	F5	A3
+41° 4676	23	1.5	+41	16	7.6	12160	G5	A3
+49° 4045		2.6	+49	40	6.85	....	F8	A3
+76° 915		20.3	+76	58	7.9	....	F5	A2
+51° 3648		30.0	+51	28	9.0	....	A	G
+45° 432		41.1	+45	52	5.09	....	K0	A5
+61° 2533		44.0	+61	40	5.61	....	A2p	G
-19° 6533		48.6	-18	56	7.42	....	G5	A3
+53° 3267		54.5	+54	8	8.0	....	F5	A3

REMARKS.

- | | |
|--|---|
| <p><i>h.</i> <i>m.</i>
2 42.4. Bu. 1433. P. A. 333°.6, Dist. 1".56, magn. 7.8 and 12.7. The brighter star must be a close double, since the star of magn. 12.7 is probably too faint to affect the photographic spectrum.</p> <p>19 39.8. Bu. 9569. P. A. 295°.2, Dist. 0".57, magn. 6.5 and 10.0. The brighter component is probably double, since the component of the tenth magnitude may be too faint to affect the photographic spectrum.</p> | <p><i>h.</i> <i>m.</i>
19 41.2. The two spectra appear to be nearly equally bright. The hydrogen lines are very narrow.</p> <p>19 48.1. The spectrum has the strontium line 4077.9, and the silicon lines 4128.1, 4131.1 very strong. The presence of the spectrum of Class A is seen in the increased strength of Hδ, Hϵ, etc., and decreased intensity of line K.</p> <p>23 44.0. The lines are narrow in the spectrum of Class A2.</p> |
|--|---|

The brighter component of the wide double star β Cygni is typical of a large number of composite spectra. It was one of the first of such spectra found on the Harvard plates, and was described by Miss Maury in H.A. 28,



Ko
COMPOSITE
B9

H ζ K H ϵ H δ H γ H β

1. SPECTRUM OF κ AURIGAE, MAGNITUDE 4.45.
2. SPECTRUM OF THE BRIGHTER COMPONENT OF β CYGNI, MAGNITUDE 3.24.
3. SPECTRUM OF THE FAINTER COMPONENT OF β CYGNI, MAGNITUDE 5.36.

99, published in 1897. The recent confirmation of the duplicity of this star by means of the variable radial velocity found on the plates taken with the Mills spectrograph is stated by Professor Campbell in Publications of the Astronomical Society of the Pacific 31, 37. The accompanying plate is inserted to illustrate the peculiar nature of this spectrum, which is the central one of the figure. The lower one is that of the fainter component of β Cygni. They are enlarged five times from the original, which was taken on August 15, 1910, with the 11-inch Draper Telescope. The upper spectrum, which is that of κ Aurigae, Class K0, is inserted for purposes of comparison. It is readily seen that characteristics of both the upper and lower spectra are combined in the central one. From the end of greater wave length to $H\epsilon$, it resembles the upper spectrum, Class K0, except that $H\delta$ is stronger. The calcium band K is, however, much weaker in the central spectrum and is intermediate between its intensity in the upper and lower spectrum, while the wide absorption line $H\zeta$ is as strong as in the lower spectrum. Thus the composite spectrum is of Class K0, except towards the violet end where it is of Class A. On the original plate, the dark lines $H\eta$ and $H\theta$ are also present as in Class A. It is probable that many of the stars in Table I are spectroscopic binaries, and a study of their radial velocities with some of the powerful instruments now available would be of great interest.

STARS HAVING PECULIAR SPECTRA. SIX NEW VARIABLE STARS.

A photograph of the spectrum of μ Centauri taken at Arequipa with the 13-inch Boyden Telescope on May 31, 1919, confirms the total disappearance of the bright hydrogen lines, as found by Professor Perrine and announced in the Report of the Twenty-Second Meeting of the American Astronomical Society. Photographs taken with the same instrument in 1892, 1894, 1896, and 1897, show the presence of strong emission at $H\beta$, $H\gamma$, $H\delta$, and fainter emission, at $H\epsilon$. A plate taken with the 8-inch Bache Telescope on June 4, 1912, was used for the regular observations of the Henry Draper Catalogue. The lines $H\gamma$, $H\delta$ and $H\epsilon$ are wholly dark on this plate. The record of the original observation reads, " $H\beta$ not distinctly seen. Bright?" It thus appears probable that the disappearance of the bright lines has been somewhat gradual.

Photographs have been taken of the spectra of several Algol variables when at minimum light. The only successful one so far obtained is that of the fainter component of U Cephei, which is of Class K0, in contrast to the

spectrum of the brighter star, Class A0. This was reported at the New York meeting of the American Astronomical Society in December, 1916, but has not been referred to in these circulars. Several attempts have been made to obtain the spectrum of the fainter component of S Cancri, but only an indistinct haze is seen, which, however, bears some resemblance to Class K0 in the distribution of light.

Table II gives an additional list of stars having peculiar spectra. The successive columns contain the Durchmusterung number, the right ascension for 1900, the declination for 1900, the photometric magnitude for the stars which are not variable, the class of spectrum, and brief remarks. When the spectrum has been found to be variable, the class at maximum is given in the fifth column.

TABLE II.

STARS HAVING PECULIAR SPECTRA. SIX NEW VARIABLE STARS.

DM.	R.A. 1900.	Dec.	Magn.	Sp.	Remarks.
	<i>h. m.</i>	<i>° '</i>			
54	0 18.5	+28 51	var.	A3	SW Andromedae. Spectrum changes to Class F8.
165	0 49.0	+58 1	var.	Pec.	W Cassiopeiae. H β and H γ bright.
..	1 6.8	+21 41	var.	Md	X Piscium. H γ and H δ bright.
1109	5 51.0	+22 50	var.	Mb	H. V. 3523.
..	7 0.9	-75 50	var.	Mb	H. V. 3524.
417	7 10.9	+69 51	var.	R0	RU Camelopardalis. Spectrum changes.
2171	7 37.5	-10 39	var.	Pec.	H. V. 3525.
1725	10 5.3	+49 58	6.82	K5p	
3425	10 25.4	-57 6	var.	F2	UX Carinae. Spectrum changes to Class G5.
..	10 26.7	-71 34	..	Pec.	H β and H γ bright.
5776	12 48.4	-57 53	var.	F5	S Crucis. Spectrum changes to Class G5.
1567	13 3.9	-70 16	9.62	Bp	H β bright.
5960	13 44.0	-57 5	var.	G5p	H. V. 2947.
6296	14 25.4	-56 27	var.	F5	V Centauri. Spectrum changes to Class G5.
..	14 51.3	-67 17	..	N	
2753	15 10.8	-66 8	var.	F5	R Triang. Aust. Spectrum changes to Class G5.
11607	16 51.8	-33 27	var.	F5	RV Scorpii. Spectrum changes to Class G5.
13142	17 34.4	-32 10	var.	K0	H. V. 3526.
3899	19 3.2	+ 1 9	var.	G5	TT Aquilae. Spectrum changes to Class K2.
..	19 43.7	+ 3 27	var.	Me	H. V. 3527.
13940	20 4.6	-36 21	5.34	K5p	
..	20 9.6	+ 4 30	var.	Md	H. V. 3528.
3881	20 15.5	+37 28	8.8	Bp	H β bright.
4134	20 39.7	+34 43	9.8	R3	
4368	20 51.6	+39 55	7.02	B0p	H β bright.
14192	21 11.5	-39 15	6.65	Map	

REMARKS.

- h. m.*
 0 49.0. W Cassiopeiae. The continuous portion is faint, but it is not of Class M. It appears to resemble the spectrum of R Andromedae, which is peculiar.
 5 51.0. — Orionis. The variability was found while selecting a spectrum plate for the Henry Draper Catalogue. It was confirmed by the examination of 15 chart plates taken between November 3, 1904 and January 9, 1915. The range is from magn. 9.5 to 10.1.
 7 0.9. — Mensae. This star is contained in the Henry Draper Catalogue, but is not in the Cape Photographic Durchmusterung. For this reason, it was observed by Miss Mary D. Applegate, the Charles S. Hinchman Fellow in Astronomy, who discovered the variability. She has measured its light on 185 photographs taken between April 17, 1894 and April 3, 1918. The variation is between the magnitudes 10.5 and 12.5, and the period is irregular.
 7 10.9. RU Camelopardalis. The fact that this is the only variable star of short period whose spectrum is of Class R was stated in H. C. 178. Observations for the Henry Draper Catalogue show that the dark bands characteristic of Class R are of much greater intensity at minimum than at maximum light. In the latter phase, it is more nearly like Class K0.
 7 37.5. — Monocerotis. An examination of 25 photographs taken between May 8, 1900 and February 5, 1919 shows a variation from magn. 10.0 to 10.7. The spectrum has strong dark bands between $H\beta$ and $H\gamma$, resembling Class N, but on plates stained with pinacyanol, it resembles Class Mc in the portion of greater wave length than $H\beta$.
 10 5.3. The spectrum resembles that of 61 Cygni, but is more peculiar. Line 4226.9 is very strong. Parallax $0''.177$. Proper motion, $1''.45$, $248^\circ.9$.
- h. m.*
 10 26.7. The spectrum appears to be continuous, except that the hydrogen lines are bright. It may be of Class B.
 13 44.0. — Centauri. The spectrum has a bright band near the wave length 4600, and bears some resemblance to the spectrum of π Crui between $H\beta$ and $H\gamma$.
 17 34.4. — Scorpii. In N. G. C. 6405, Messier 6. The variability was noticed while superposing two spectrum plates for the Henry Draper Catalogue. The spectrum is faint on a photograph taken August 7, 1919. Miss Dorothy W. Block, the Pickering Fellow in Astronomy, has measured its light on 303 photographs. The range of variation is from magn. 7.8 to 8.7. The light curve is irregular and resembles that of R Scuti.
 19 43.7. — Aquilae. The position for 1855 is R. A. $19^h 41^m 21^s.7$, Dec. $+3^\circ 20'.$ The variability was found while selecting spectrum plates for the Henry Draper Catalogue. It was confirmed on 12 chart plates taken between September 12, 1892 and April 28, 1902. The range is from magn. 10.5 to 11.6.
 20 4.6. The spectrum resembles that of 61 Cygni. Proper motion $1''.70$, $164^\circ.7$.
 20 9.6. — Aquilae. The position for 1855 is R. A. $20^h 7^m 26^s.4$, Dec. $+4^\circ 21'.$ On a photograph taken June 6, 1907, the spectrum is of Class Mc, having the line $H\delta$ twice as bright as $H\gamma$. The variation was confirmed on 10 chart plates taken between May 30, 1891 and June 4, 1908. The range of variation is from magn. 10.2 to <12.0 . The period is long.
 21 11.5. The absorption lines characteristic of stars of low temperature are very strong in this spectrum. Proper motion $3''.46$, $249^\circ.4$.

It appears that attention was first called to a change in the spectrum of a variable star of short period in H. C. 129, published May 10, 1907. It was there stated that the spectrum of the Cepheid variable, TT Aquilae, 190301, was of Class G at maximum, and of Class K at minimum. The change in that spectrum and similar changes in several other variables of the same class were also obvious from discordant classification on two or more plates used for the Henry Draper Catalogue. An examination has not yet been made of all the spectra of the Cepheid variables which appear on the Harvard photographs, but, from the observations of Shapley and others, it appears that such changes are closely connected with variability in short period.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 222.

PREDICTED MAXIMA AND MINIMA IN 1921 OF VARIABLE STARS.

PREDICTED dates of maxima for variable stars of long period have been published for several years past in these circulars. To meet requests for the corresponding dates of minima, the following table gives the predicted times of both maxima and minima. The successive columns give the designation number, the name, and the predicted dates of maximum and minimum for each star.

TABLE I.

PREDICTED MAXIMA AND MINIMA.

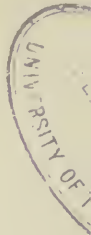
Des.	Name.	1921		Des.	Name.	1921		Des.	Name.	1921	
		Max.	Min.			Max.	Min.			Max.	Min.
000339	V Sculptoris	m. d.	m. d.	011712	U Piscium	m. d.	m. d.	025751	T Horologii	m. d.	m. d.
001032	S "	7 3	3 16	"	"	4 8	1 1	030514	U Arietis	...	10 7
001046	X Androm.	11 8	6 20	012350	RZ Persei	9 27	6 22	031401	X Ceti	5 22	12 1
001726	T "	11 8	6 23	012502	R Piscium	4 24	12 10	"	"	2 22	6 4
"	"	2 6	7 1	"	"	6 26	1 18	032043	Y Persei	8 16	11 26
"	"	11 18	...	"	"	...	12 28	"	"	3 21	7 16
001755	T Cassiop.	3 27	10 9	013238	RU Androm.	1 4	5 5	"	"	11 25	...
001838	R Androm.	1 8	9 26	"	"	9 9	...	032335	R "	7 19	4 14
001862	S Tucanae	8 9	4 20	013338	Y "	3 31	7 16	"	"	...	11 8
001909	S Ceti	2 22	8 20	"	"	11 2	...	034625	U Eridani	3 4	8 7
002438a	T Sculptoris	3 22	7 11	014958	X Cassiop.	2 3	7 3	"	"	10 27	...
"	"	10 10	...	015354	U Persei	4 6	9 27	035124	T "	8 21	5 8
002546	T Phoenicis	3 28	8 24	015912	S Arietis	10 7	6 1	040725	W "	12 4	8 13
003179	Y Cephei	5 14	11 26	021024	R "	4 22	1 20	042209	R Tauri	9 30	5 18
004047	U Cassiop.	2 1	7 10	"	"	10 25	7 25	042215	W "	4 26	9 11
"	"	11 4	...	021143a	W Androm.	9 21	3 20	042309	S "	6 7	12 21
004132	RW Androm.	5 30	...	021281	Z Cephei	7 17	2 25	043065	T Camelop.	6 1	12 14
004435	V "	9 1	5 13	"	"	...	12 4	"	RX Tauri	6 30	1 21
004435	X Sculptoris	6 6	2 12	021403	o Ceti	5 22	1 11	"	"	...	12 27
"	"	...	10 20	"	"	...	12 9	043263	R Reticuli	3 9	8 18
004533	RR Androm.	3 12	10 11	021558	S Persei	10 15	...	"	"	12 7	...
004746a	RV Cassiop.	2 28	9 24	022000	R Ceti	2 3	5 4	043274	X Camelop.	4 9	1 31
004958	W "	...	7 14	"	"	7 17	10 16	"	"	8 30	6 23
005475	U Tucanae	3 12	8 5	"	"	12 30	...	"	"	...	11 13
"	"	11 26	...	022150	RR Persei	1 30	11 29	043738	R Caeli	1 10	9 9
010102	Z Ceti	4 9	1 4	022436	R Fornacis	7 21	1 26	044349	R Pictoris	2 3	3 1
"	"	10 11	7 19	022813	U Ceti	7 23	4 4	"	"	7 17	8 13
010630	U Sculptoris	2 19	9 23	"	"	...	11 26	044617	V Tauri	2 8	5 11
010940	U Androm.	7 13	2 7	022980	RR Cephei	5 16	12 31	"	"	7 29	10 28
011041	UZ "	6 11	2 15	023133	R Trianguli	4 29	1 2	045307	R Orionis	6 28	1 30
"	"	...	12 22	"	"	...	9 27	045514	R Leporis	7 1	12 24
011208	S Piscium	9 3	3 13	025050	R Horologii	6 13	1 30	050003	V Orionis	3 31	8 13
011272	S Cassiop.	12 4	3 27	025751	T "	6 19	3 3	050022	T Leporis	2 2	8 21

Des.	Name.	1921		Des.	Name.	1921		Des.	Name.	1921	
		Max.	Min.			Max.	Min.			Max.	Min.
050848	S Pictoris	m. d. 9 4	m. d. 4 21	081112	R Cancr	m. d. 4 7	m. d. 9 29	122532	T Can. Ven.	m. d. 11 28	m. d. ...
050953	R Aurigae	8 10	...	081617	V "	5 4	1 1	122803	Y Virginis	6 24	3 25
051247	T Pictoris	5 22	3 1	" "	" "	...	9 29	" "	" "	...	10 30
" "	" "	12 8	9 17	082476	R Chamael.	9 21	5 16	122854	U Centauri	3 27	7 22
051533	T Columbae	3 31	7 31	083019	U Cancr	10 5	6 17	" "	" "	11 1	...
" "	" "	11 11	...	083350	X Urs. Maj.	3 26	7 27	123160	T Urs. Maj.	4 26	9 8
052036	W Aurigae	8 4	4 17	" " "	" " "	11 28	...	123307	R Virginis	3 28	1 17
052404	S Orionis	7 26	1 2	084803	S Hydrae	7 30	3 27	" "	" "	8 19	6 12
053068	S Camelop.	3 3	8 8	085008	T "	6 27	2 6	" "	" "	...	11 6
053531	U Aurigae	3 17	11 24	" "	" "	...	11 22	123459	RS Urs. Maj.	9 3	5 26
054331	S Columbae	10 11	6 11	090024	S Pyxidis	2 7	5 22	123961	S " "	1 1	5 2
054615a	Z Tauri	...	6 9	" "	" "	9 3	12 16	" " "	" " "	8 24	12 14
054629	R Columbae	11 6	6 21	090425	W Cancr	11 20	7 2	124204	RU Virginis	11 24	6 9
054920	U Orionis	7 30	3 15	091868	RW Carinae	1 20	7 26	124606	U "	5 19	2 5
054974	V Camelop.	9 1	4 29	092551	Y Velorum	11 6	6 9	" "	" "	12 11	9 9
055353	Z Aurigae	1 12	3 9	092962	R Carinae	6 18	1 31	130212	RV "	1 14	4 18
" "	" "	5 3	6 28	" "	" "	...	12 6	" "	" "	8 2	11 14
" "	" "	8 22	10 17	093014	X Hydrae	1 21	7 26	131283	U Octantis	5 16	1 1
055686	R Octantis	9 14	3 1	" "	" "	11 22	...	" "	" "	...	10 29
060450	X Aurigae	5 7	2 24	093178	Y Draconis	10 5	5 9	132202	V Virginis	2 9	7 27
" "	" "	10 16	8 7	093934	R Leo. Min.	2 28	10 8	" "	" "	10 17	...
061647	V "	9 11	3 10	094023	RR Hydrae	11 19	6 10	132422	R Hydrae	12 6	5 27
061702	V Monoc.	6 5	1 2	094211	R Leonis	1 12	7 12	132706	S Virginis	2 19	11 18
063159	U Lynceis	7 31	2 7	" "	" "	11 22	...	133273	T Urs. Min.	9 18	5 7
063558	S "	10 1	6 7	094953	Z Velorum	6 5	...	133633	T Centauri	1 18	3 3
064030	X Gemin.	8 19	4 14	095421	V Leonis	3 13	8 9	" "	" "	4 18	6 1
" "	" "	...	12 31	095563	RV Carinae	5 8	12 6	" "	" "	7 17	8 30
064707	W Monoc.	8 14	3 31	100661	S Carinae	5 8	2 17	" "	" "	10 15	11 28
" "	" "	...	12 19	" "	" "	10 4	7 16	134236	RT "	8 20	5 12
065111	Y "	7 9	3 21	101058	Z "	9 29	4 20	134440	R Can. Ven.	6 5	1 22
" "	" "	...	11 1	101153	W Velorum	7 5	1 30	" "	" " "	...	12 14
065355	R Lynceis	5 19	12 27	103270	RZ Carinae	2 6	5 18	134536	RX Centauri	3 5	11 18
070109	V Can. Min.	9 18	5 18	103769	R Urs. Maj.	9 30	6 7	134677	T Apodis	6 6	4 4
070122a	R Gemin.	10 31	6 22	104620	V Hydrae	11 11	2 9	" "	" "	...	11 23
070310	R Can. Min.	2 5	7 29	104628	RS "	10 19	6 23	135908	RR Virginis	1 16	5 12
070772	R Volantis	4 3	12 6	104814	W Leonis	1 29	10 27	" "	" "	8 25	12 18
071044	L ² Puppis	5 15	3 6	110506	S "	3 4	5 22	140113	Z Bootis	5 18	1 18
" "	" "	10 2	7 24	" "	" "	9 9	11 27	" "	" "	...	10 29
071201	RR Monoc.	8 6	3 1	111661	RS Centauri	2 27	5 15	140512	Z Virginis	9 9	4 21
071713	V Gemin.	8 29	5 11	" "	" "	8 12	10 28	140528	RU Hydrae	7 16	2 19
072708	S Can. Min.	6 31	1 10	114441	X "	3 27	10 3	140959	R Centauri	...	5 25
072811	T " "	3 29	10 6	115058	W "	6 3	3 3	141567	U Urs. Min.	5 22	10 25
072820b	Z Puppis	1 24	10 13	" "	" "	...	9 22	141954	S Bootis	1 27	6 10
073173	S Volantis	10 21	4 26	115919	R Comae	6 15	2 9	" "	" "	10 24	...
073508	U Can. Min.	9 17	3 10	120012	SU Virginis	7 24	4 6	142205	RS Virginis	4 14	12 1
073723	S Gemin.	4 12	9 27	" "	" "	...	11 3	142539	V Bootis	7 21	3 24
074241	W Puppis	4 20	2 23	120905	T "	9 22	4 20	142584	R Camelop.	8 26	5 6
" "	" "	8 19	6 24	121418	R Corvi	6 2	1 10	143227	R Bootis	5 14	2 3
" "	" "	12 18	10 23	" "	" "	...	11 24	" "	" "	12 23	9 15
074323	T Gemin.	4 20	9 22	122532	T Can. Ven.	2 20	8 11	143417	V Librae	7 6	3 5

Des.	Name.	1921		Des.	Name.	1921		Des.	Name.	1921	
		Max.	Min.			Max.	Min.			Max.	Min.
		<i>m. d.</i>	<i>m. d.</i>			<i>m. d.</i>	<i>m. d.</i>			<i>m. d.</i>	<i>m. d.</i>
143417	V Librae	...	11 16	161138	W Cor. Bor.	3 4	7 8	180531	T Herculis	6 23	9 18
145254	Y Lupi	12 31	9 11	"	" " "	10 27	...	180565	W Draconis	1 1	6 5
150018	RT Librae	6 25	3 5	161007	W Ophiuchi	4 20	10 31	"	"	9 9	...
"	"	...	11 18	162112	V	1 31	7 11	180666	X	5 30	1 22
150519	T	5 9	9 5	"	"	11 29	...	"	"	...	10 18
150605	Y	5 8	1 28	162119	U Herculis	1 4	7 29	181103	RY Ophiuchi	4 16	2 4
"	"	...	11 1	162319	Y Scorpii	10 2	4 2	"	"	9 15	7 7
151520	S	4 17	1 3	162807	SS Herculis	3 13	1 22	"	"	...	12 8
"	"	10 26	7 15	"	"	6 21	5 2	181136	W Lyrae	6 22	3 23
151714	S Serpentis	8 18	3 19	"	"	9 29	8 10	"	"	...	10 5
151731	S Cor. Bor.	1 18	9 9	"	"	...	11 18	182133	RV Sagittar.	6 17	4 7
151822	RS Librae	2 26	6 12	162815	T Ophiuchi	4 23	10 20	182224	SV Herculis	2 5	7 8
"	"	10 1	...	162816	S	7 14	3 19	"	"	10 1	...
152714	RU	7 16	2 5	"	"	...	11 8	182306	T Serpentis	3 13	9 28
"	"	...	12 16	163137	W Herculis	8 16	3 26	183149	SV Draconis	2 27	7 18
152849	R Normae	3 1	...	163266	R Draconis	8 22	4 27	"	"	11 12	...
153215	U	6 21	3 1	164319	RR Ophiuchi	1 30	7 19	183225	RZ Herculis	3 23	10 13
"	"	...	9 22	"	"	11 24	...	183308	X Ophiuchi	5 14	10 25
153378	S Urs. Min.	8 21	3 24	164715	S Herculis	4 7	9 21	184134	RY Lyrae	6 12	2 4
153620a	U Librae	4 25	1 1	164844	RS Scorpii	10 8	6 17	"	"	...	12 29
"	"	12 6	8 14	165030	RR	5 2	10 1	184243	RW	7 29	3 7
153654	T Normae	3 10	8 10	165202	SS Ophiuchi	4 10	1 10	185032	RX	1 20	6 1
"	"	11 8	...	"	"	11 26	8 28	"	"	9 25	...
154536	X Cor. Bor.	2 12	6 27	165631	RV Herculis	3 28	7 9	185512	ST Sagittarii	1 19	8 8
"	"	10 19	...	"	"	10 17	...	185634	Z Lyrae	1 30	6 24
154615	R Serpentis	3 1	10 21	165636	RT Scorpii	...	9 29	"	"	11 16	...
154639	V Cor. Bor.	1 1	7 13	170215	R Ophiuchi	4 1	9 7	185737	RT	2 17	6 10
154715	R Librae	4 10	1 8	170627	RT Herculis	4 1	9 7	"	"	10 24	...
"	"	12 8	9 7	170833	RW Scorpii	2 3	10 3	190108	R Aquilae	10 17	5 3
154736	R Lupi	1 14	5 24	171401	Z Ophiuchi	2 23	8 23	190529a	V Lyrae	5 20	12 16
"	"	9 5	...	171723	RS Herculis	2 27	7 14	190818b	RX Sagittar.	2 22	8 7
155018	RR Librae	9 23	5 20	"	"	10 7	...	190925	S Lyrae	1 26	11 28
155229	Z Cor. Bor.	1 10	5 5	172586	S Octantis	6 18	11 6	190933	RS	3 12	8 15
"	"	9 10	...	172809	RU Ophiuchi	5 20	2 15	190941	RU	12 6	6 12
155823	RZ Scorpii	1 1	3 23	"	"	12 8	10 5	190967	U Draconis	3 31	10 3
"	"	6 11	8 31	173543	RU Scorpii	12 19	5 26	191007	W Aquilae	10 9	3 11
"	"	11 19	...	174135	SV	2 21	6 21	191017	T Sagittarii	4 16	12 6
160021	Z	12 26	7 13	"	"	11 6	...	191019	R	9 17	5 30
160118	R Herculis	6 18	2 19	174162	W Pavonis	6 6	3 6	191124	TY	4 25	1 4
160210	U Serpentis	5 14	2 4	"	"	...	12 13	"	"	...	11 24
"	"	...	10 2	174551	U Arae	3 3	7 12	191319	S	1 2	4 21
160221a	X Scorpii	3 1	5 20	"	"	10 13	...	"	"	8 21	12 8
"	"	9 17	12 6	175111	RT Ophiuchi	12 2	6 15	191321	Z	11 24	6 11
160519	W	5 2	1 11	175458a	T Draconis	7 25	...	191331	SW	1 28	7 21
"	"	12 10	8 21	175519	RY Herculis	6 25	3 24	"	"	11 14	...
160625	RU Herculis	11 24	6 29	"	"	...	11 2	191637	U Lyrae	8 22	1 12
161122a	R Scorpii	3 25	7 27	175654	V Draconis	3 14	8 20	192928	TY Cygni	1 2	7 25
"	"	11 4	...	180363	R Pavonis	1 7	5 7	193311	RT Aquilae	10 17	6 9
161122b	S	4 14	1 14	"	"	8 23	12 22	193449	R Cygni	3 23	8 29
"	"	10 5	7 10	180531	T Herculis	1 8	4 7	193509	RV Aquilae	2 21	6 1

Des.	Name.	1921		Des.	Name.	1921		Des.	Name.	1921	
		Max.	Min.			Max.	Min.			Max.	Min.
193509	RV Aquilae	m. d. 9 29	m. d. . . .	203816	S Delphini	m. d. 5 27	m. d. 1 10	215605	V Pegasi	m. d. 2 27	m. d. 8 2
193972	T-Pavonis	6 6	2 7	"	"	. . .	10 14	215828	S Pisc. Aust.	3 18	9 7
"	"	. . .	10 20	203847	V Cygni	9 8	1 10	215934	RT Pegasi	3 16	7 1
194048	RT Cygni	1 24	4 30	203905	Y Aquarii	6 19	1 30	"	"	10 17	. . .
"	"	8 4	11 8	204016	T Delphini	1 30	7 30	220412	T	6 17	3 3
194343	TU	5 4	1 19	204104	W Aquarii	5 7	9 18	220613	Y	3 11	7 4
"	"	12 9	8 29	204215	U Capric.	7 3	3 23	"	"	10 3	. . .
194604	X Aquilae	3 9	9 19	"	"	. . .	10 11	220714	RS	8 28	3 31
194632	X Cygni	8 9	3 13	204318	V Delphini	9 1	3 17	221230	R Pisc. Aust.	8 29	4 5
194659	S Pavonis	12 10	6 13	204405	T Aquarii	3 25	7 7	221321	X Aquarii	1 26	7 3
194920	RR Sagittar.	3 13	9 18	"	"	10 14	. . .	221722	RT	8 4	4 20
195142	RU	1 2	5 27	204846	RZ Cygni	7 18	3 31	221938	T Gruis	1 5	3 19
"	"	9 2	. . .	204954	S Indi	12 6	7 3	"	"	5 21	8 2
195202	RR Aquilae	6 3	1 10	205017	X Delphini	1 15	6 25	"	"	10 4	12 16
195308	RS	8 4	1 10	"	"	10 23	. . .	221948	S	10 8	5 13
195849	Z Cygni	1 3	6 17	205030a	UX Cygni	5 5	. . .	222129	RV Pegasi	10 8	5 30
"	"	9 27	. . .	205627	RR Capric.	8 6	5 10	222439	S Lacertae	1 2	5 8
200212	SY Aquilae	3 25	9 17	205923	R Vulpec.	3 10	1 2	"	"	8 28	12 31
200357	S Cygni	4 28	11 4	"	"	7 25	5 19	223462	T Tucanae	7 23	3 3
200514	R Capric.	7 11	3 1	"	"	12 9	10 3	"	"	. . .	12 9
200715a	S Aquilae	2 10	4 26	210124	V Capric.	4 15	2 21	223841	R Lacertae	8 30	5 12
"	"	7 7	9 20	"	"	9 19	7 27	225120	X Aquarii	3 24	9 17
"	"	12 1	. . .	210129	TW Cygni	3 1	9 9	225914	RW Pegasi	3 21	6 30
200747	R Telescopii	3 13	10 3	210221	X Capric.	6 3	2 23	"	"	10 16	. . .
200812	RT Aquilae	8 23	4 30	"	"	. . .	9 29	230110	R	3 9	9 26
200822	W Capric.	6 21	3 15	210382	X Cephei	9 20	4 20	230759	V Cassiop.	6 27	2 24
"	"	. . .	10 8	210504	RS Aquarii	4 29	2 9	"	"	. . .	10 15
200906	Z Aquilae	4 8	1 28	"	"	11 29	9 11	231425	W Pegasi	2 20	8 9
"	"	8 14	6 2	210516	Z Capric.	7 25	3 1	231508	S	8 28	4 18
"	"	12 20	10 8	210812	R Equulei	7 6	3 9	232746	V Phoenicis	5 15	1 24
200938	RS Cygni	. . .	3 31	"	"	. . .	11 26	"	"	. . .	10 3
201003	R Delphini	9 27	5 6	210868	T Cephei	4 6	10 17	233335	ST Androm.	1 22	7 29
201130	SX Cygni	1 16	6 26	210903	RR Aquarii	2 20	6 13	"	"	11 28	. . .
201139	RT Sagittar.	5 4	10 13	"	"	8 19	12 10	233815	R Aquarii	1 1	9 11
201647	U Cygni	1 24	8 25	211614	X Pegasi	3 5	6 25	233956	Z Cassiop.	11 16	4 30
202240	U Microsc.	5 2	1 4	"	"	9 21	. . .	235053	RR	5 7	7 27
"	"	. . .	12 3	211615	T Capric.	5 3	1 10	235150	R Phoenicis	5 28	2 1
202622	RU Capric.	7 3	1 14	"	"	. . .	10 6	"	"	. . .	10 29
"	"	. . .	12 21	212030	S Microscop.	1 26	5 30	235209	V Ceti	8 12	4 14
202817	Z Delphini	6 24	2 24	"	"	8 28	12 29	235265	R Tucanae	6 28	3 11
"	"	. . .	12 24	212814	Y Capric.	1 16	4 29	"	"	. . .	12 11
202954	ST Cygni	4 26	10 25	"	"	8 10	11 21	235350	R Cassiop.	10 21	7 9
203429	R Microsc.	4 7	1 30	213678	S Cephei	7 15	. . .	235525	Z Pegasi	6 4	2 14
"	"	8 24	6 18	214024	RR Pegasi	5 30	2 15	235715	W Ceti	7 27	3 11
"	"	. . .	11 4	"	"	. . .	11 6	235855	Y Cassiop.	1 3	9 7
203611	Y Delphini	. . .	7 16	214247	R Gruis	1 8	8 10	235939	SV Androm.	9 4	5 23

LEON CAMPBELL.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 223.

OBSERVATIONS OF SATURN'S RINGS.

THE Earth passed through the plane of the rings on November 7, and will do so again on February 22 and August 3 of the coming year. On this last date Saturn will be within less than 3 hours of the Sun, and therefore cannot be observed to advantage. By using column *B* of the Ephemeris for Saturn's Rings, which gives a more accurate value than column *b*, we find that the Earth will pass through their plane on February 22, at 8^h G. M. T. Since the planet transits the meridian at 13^h.5 local time, at 8^h G. M. T. it will be on the meridian in India, will not be visible in America, and will be at a very low altitude in western Europe.

Observations of the rings made just before the November transit, and others of their shadow made since then, lead us to believe that while the outer rings are extremely thin, as is well known, the crepe ring has a very appreciable thickness, of not far from 2000 miles (3200 km.). These measurements were made with the Direct Vision Scale, described in our Report on Mars, No. 7, Popular Astronomy, 1914, 22, 617. By means of this scale it is possible to measure the breadth of any narrow line to within 0".05. It is indeed the only method by which the breadth of such a line can be measured accurately. It is true that all such measures, made by any method whatsoever require a certain systematic correction to be applied to them, as suggested in my original paper. Otherwise they are but little better than guesswork. This will be dealt with later in another place, the object of the present article being merely to call immediate attention to the results.

The rings of the planet are now readily visible by transmitted light, the Sun and Earth being on opposite sides of their plane. Immediately after the November transit, however, they could not be seen, and it is thought possible that they may again disappear by the middle of February, reappearing again after the Earth transits their plane February 22. On account of the thickness of the crepe ring, its reappearance should occur somewhat before this takes place, and observers on the Pacific Coast may be particularly well

located to observe this phenomenon shortly before sunrise. Whether other observers will be able to see it, and how early it will become visible will depend largely on the brightness of the illumination, as well as on the thickness of the crepe ring itself, and the light gathering capacity of the telescope. It is possible that the second ring near its inner edge may also have an appreciable thickness. The dark line down the middle of the shadow, first noticed by Lowell, has been recorded here.

WILLIAM H. PICKERING.

MANDEVILLE, JAMAICA, B.W.I.,
DECEMBER 16, 1920.

VENUS.

VAGUE markings, but rather more distinct than usual, are now visible on Venus. They change from day to day, and appear to be real.

CONDENSATIONS ON THE RINGS OF SATURN.

It seems that not only does the crepe ring of Saturn have an appreciable thickness, but that in the outer edge of the second ring the meteors constituting it are more concentrated than elsewhere. These two diverse causes appear to furnish the explanation of the condensations, two of which are now readily visible on each side of the planet, as noticed by Professor Barnard, *Harvard Bulletin*, 734. On November 13 no trace of the ring could be seen here by transmitted light, using a magnification of 330. On November 29 with magnification 210 we first saw the ring, and the inner preceding condensation. On December 7 the ring was seen with ease with magnification 210, and also even with 660. It was recorded as most readily visible near the planet. This was doubtless due to the two inner condensations. The shadow of Rhea was not visible, seeing 8. On December 16 one condensation was visible with magnification 330. The shadow of Rhea was not visible, seeing 8.

December 25. The ring was not so easy as Tethys near elongation, but easier than Dione when 23° past conjunction with the planet. The two inner condensations were readily seen with magnification 165 and also the two outer ones. They all came out much more clearly with a power of 90. The

inner pair were 0.4 of a magnitude fainter than Dione, and the outer pair 0.8 fainter. With this low power the ring was as easy as Tethys. It did not seem worth while to measure the distance of the condensations from the centre of the planet, since this had already been done by Barnard, M. N. 1908, 88, 365, and also by Lowell, Lowell Bulletin 32, their results being in general quite accordant. The positions were estimated, however, by two independent methods, which gave results in close agreement. In terms of equatorial radii of the planet their distances were 1.40 and 1.79. Lowell gives them as 1.28 and 1.82. It is clear that a very low power should be used to see them, but the details of the shadow of the ring on the ball are best seen with a much higher magnification. The shadow of Rhea was invisible though carefully looked for with varying magnifications under the most favorable conditions, — seeing 11 and 12. This makes it practically certain that it is invisible under any circumstances with an aperture as small as 11 inches, and it is clear that the best of seeing would be required in order to see it with any aperture, however large.

It appears that when the Sun and Earth are on opposite sides of the ring, the ring becomes easier and easier to see as the Earth recedes from its plane. When near the plane it is doubtful if the condensations are visible at all. This indicates that they, as well as the rings, are thin in proportion to their width. Since no condensations are seen at the outer edge of the outer ring, we conclude that the meteors there are not sufficiently concentrated to produce this effect. This explanation is corroborated by the comparative faintness of the outer ring at all times. Barnard finds the outer edge of the outer condensation extends beyond the outer edge of the rim of ring B. Lowell finds that it falls just within it. The latter result appears more probable on the face of it.

WILLIAM H. PICKERING.

MANDEVILLE, JAMAICA, B.W.I.
JANUARY 3, 1921.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 224.

STARS HAVING PECULIAR SPECTRA. 16 NEW VARIABLE STARS.

LISTS of peculiar spectra found during the observations for the Henry Draper Catalogue were published in H. C. 178, 184, 196, and 221. An examination of some photographs which show fainter stars than those previously classified has led to the discovery of nearly all the spectra given in Table I. The photographs were taken either with the 24-inch Bruce Telescope, or with the 8-inch Bache Telescope having the spectra very narrow, so that while the brighter objects are burned out, much fainter spectra can be classified. The list includes one new spectrum of Class Oa, two of Class B having $H\beta$ bright, two of the so-called P Cygni Type, six of Class R, seven of Class P, the gaseous nebulae, and fifteen of Class Md, characteristic of variable stars of long period. Since but one new gaseous nebula was found during the observations of the 225,000 stars for the Draper Catalogue, it has been thought that we may have reached the limit of such objects. It appears, however, that fainter nebulae, both of the planetary and diffuse type, exist.

The identifications, confirmation of variability, and measurements of position for those objects not contained in the Durchmusterung have been made by Miss Wells and Miss Walker.

The successive columns of Table I give the Durchmusterung zone and number, the right ascension for 1900, the declination for 1900, the Durchmusterung magnitude, the class of spectrum, and a brief description of the observed peculiarity. Additional information is given in the Remarks following the Table.

Attention was called in H.A. 28, 183, Remark 98, to the variability of the hydrogen lines in the spectrum of J Velorum, R. A. $10^h 17^m.2$, Dec. $-55^\circ 33'$, magn. 4.65. On a photograph of the spectrum taken with the 13-inch Boyden Telescope on June 2, 1893, $H\beta$ and $H\gamma$ were well-marked bright lines, superposed on wide dark bands. Eleven later plates, taken in 1895, 1896,

TABLE I.

STARS HAVING PECULIAR SPECTRA. 16 NEW VARIABLE STARS.

DM.	R.A. 1900.	Dec. 1900.	Magn.	Sp.	Description.
	<i>h. m.</i>	<i>° ' "</i>			
..	1 21.6	-73 40	..	Pd	Gaseous nebula in the Small Magellanic Cloud.
-50° 5170	10 24.2	-50 40	10.0	Md	- Velorum. Variable. H. V. 3533.
R	10 46.1	-48 9	10.0	Md	- Velorum. Variable. H. V. 3534.
-63° 2166	12 4.8	-63 26	8.7	Bp	H. D. 105675. H β bright.
..	12 38.0	-62 32	..	Oa	Type V or Wolf-Rayet star.
-52° 6741	13 40.9	-52 52	10.2	Pec.	- Centauri. Variable. H. V. 3535.
..	13 42.1	-37 38	..	Md	- Centauri. Variable. H. V. 3536.
-53° 5856	13 57.3	-53 14	8.6	A0p	H.D. 122525. Strontium and silicon lines strong.
-41° 9373	14 54.3	-42 5	9.6	Md	- Centauri. Variable. H. V. 3537.
..	15 2.4	-15 7	..	Md	- Librae. Variable. H. V. 3538.
..	15 23.6	-62 13	..	Np	- Trianguli Aust. Variable. H. V. 3539.
-23° 12396	15 29.5	-23 37	9.4	Md	- Librae. Variable. H. V. 3540.
-47° 10298	15 39.4	-47 45	10	Md	- Lupi. Variable. H. V. 3541.
-48° 10371	15 44.1	-48 27	10	Pd	Gaseous nebula.
-65° 3171	15 46.7	-65 52	9.2	Pec.	P Cygni type.
-61° 5587	16 3.1	-61 19	9.8	R3	
-30 °13283	16 30.2	-31 2	8.9	R5	ST Scorpii.
..	16 35.4	-62 26	..	Pf	Gaseous nebula.
..	16 45.1	-64 4	..	Pec.	P Cygni type.
-64° 3573	16 45.1	-65 2	9.5	Md	Z Trianguli Aust. H. V. 2968.
-51° 10676	16 56.9	-51 15	8.6	B3p	H β bright.
R	17 2.0	-61 49	..	Nb	- Arac. Variable. H. V. 3542.
-36° 11460	17 17.0	-36 24	9.5	R3	
..	17 19.0	-44 6	..	Pd	Gaseous nebula.
..	17 20.3	-46 50	..	Pd	Gaseous nebula.
-46° 11816	17 38.2	-46 3	9.9	Pec.	
..	17 56.4	-47 14	..	Md	- Arac. Variable. H. V. 3543.
-30° 15469	18 9.7	-30 54	10	Pec.	
-46° 12279	18 11.4	-46 36	9.5	R0	
..	18 14.6	-44 57	..	Md	- Coronae Aust. Variable. H. V. 3544.
-20° 5134	18 19.4	-20 35	4.96	K0	Spectrum composite.
..	18 19.4	-20 35	..	A0	
..	18 22.7	-31 33	..	Pd	Gaseous nebula.
..	18 27.5	-32 26	..	Md	- Sagittarii.
-38° 13089	18 40.7	-38 16	9.0	R0	V Coronae Austrinae.
-18° 5091	18 44.2	-18 33	8.8	F5	
-49° 12412	18 48.6	-49 36	11	A2	Composite Spectrum.
-32° 14673	18 49.1	-32 23	9.8	Md	- Telescopii. Variable. H. V. 3545.
+14° 3729	18 54.0	+14 14	9.0	Pd	Gaseous nebula.
-42° 13918	19 1.6	-42 31	10	Nb	UV Aquilae. Variable.
-46° 13014	19 20.3	-46 4	10	Md	- Coronae Aust. Variable. H. V. 3546.
..	19 34.5	-44 50	..	Md	- Telescopii. Variable. H. V. 3547.
-47° 13120	19 44.7	-47 36	10	Md	- Sagittarii. Variable. H. V. 3548.
				R0	

REMARKS.

- A. M.**
- 1 21.6. The position for 1875 is, R. A. $1^{\text{h}} 20^{\text{m}} 59^{\text{s}}$, Dec. $-73^{\circ} 48'.1$.
- 10 24.2 The variability was discovered by Miss Applegate in 1920, but has not been announced previously. Found independently by the writer by means of its spectrum, which is of Class Mb, having the line $\text{H}\beta$ bright. The range of variation is from magn. 10.4 to 12.5.
- 10 46.1. This star is C.P.D. $-48^{\circ} 3567$, magn. 10.0, and is not contained in the Cordoba Durchmusterung. The variability was discovered by Miss Applegate in 1920, but has not been announced previously. Found independently by the writer by means of the spectrum which is of Class Mb, having the line $\text{H}\beta$ very bright. The range of variation is from magn. 10.8 to 14.
- 12 4.8. $\text{H}\beta$ was suspected to be bright on Plate B 38828, used for the Henry Draper Catalogue. See Remark in H.A. 95. A photograph taken with the 24-inch Bruce Telescope shows $\text{H}\beta$ to be distinctly bright.
- 12 38.0. The position for 1875 is R. A. $12^{\text{h}} 36^{\text{m}} 31^{\text{s}}$, Dec. $-62^{\circ} 24'.0$. Magn. 11.
- 13 40.9. The spectrum is visible only from $\text{H}\beta$ to about 4400, and thus resembles Class N. There is, however, no trace of the wide band of absorption at 4700, as in Class N. The magnitude in the Cordoba Durchmusterung is 8.6. The range of variation is from magn. 10.4 to 11.6.
- 13 42.1. The position for 1875 is R. A. $13^{\text{h}} 40^{\text{m}} 39^{\text{s}}$, Dec. $-37^{\circ} 30'.7$. The spectrum is of Class Ma, having $\text{H}\beta$ bright. The range of variation is from magn. 11.5 to <14 .
- 13 57.3. Classified A0 in the Henry Draper Catalogue. A photograph taken with the 24-inch Bruce Telescope shows lines 4077.9, 4128.1, and 4131.1 to be strong.
- 14 54.3. The variability was discovered in 1920 by Miss Woods during the systematic search for new stars, but has not been announced previously. Found independently by the writer because of its spectrum, which appears to be of Class Ma, and has the line $\text{H}\gamma$ bright. The range of variation is from magn. 10.6 to <12.5 .
- 15 2.4. The position for 1855 is R. A. $15^{\text{h}} 0^{\text{m}} 52^{\text{s}}$, Dec. $-14^{\circ} 56'.5$. The spectrum is of Class Ma, having the line $\text{H}\beta$ 1.5 as bright as $\text{H}\gamma$. The range of variation is from magn. 10.9 to 16.
- 15 23.6. The position for 1875 is R. A. $15^{\text{h}} 21^{\text{m}} 32^{\text{s}}$, Dec. $-62^{\circ} 7'.5$. The spectrum is peculiar in the relative intensity of the bright portions. The range of variation is from magn. 12.0 to <13.2 .
- 15 29.5. The spectrum is of Class Mb, having the lines $\text{H}\gamma$ and $\text{H}\delta$ nearly equally bright. The range of variation is from magn. 11.4 to 14.5.
- 15 39.4. The spectrum is of Class Mb, having the lines $\text{H}\gamma$ and $\text{H}\delta$ equally bright. The range of variation is from magn. 10.0 to <14 .
- A. M.**
- 15 44.1. The bright lines $\text{H}\gamma$, 4959, and 5007 are seen, the last being the strongest. The image is stellar on a chart plate taken with the 24-inch Bruce Telescope.
- 15 46.7. The lines $\text{H}\beta$, $\text{H}\gamma$, $\text{H}\delta$ and $\text{H}\epsilon$ are bright and superposed on a continuous spectrum.
- 16 35.4. The position for 1875 is R. A. $16^{\text{h}} 33^{\text{m}} 10^{\text{s}}$, Dec. $-62^{\circ} 22'.7$. The line 4686 is the strongest in the spectrum. Other bright lines are $\text{H}\beta$, 4363, $\text{H}\gamma$, $\text{H}\delta$, $\text{H}\epsilon$ and $\text{H}\zeta$. The chief nebular line, 5007, if really present, is very faint. The image is stellar on chart plates.
- 16 45.1a. The position for 1875 is R. A. $16^{\text{h}} 42^{\text{m}} 43^{\text{s}}$, Dec. $-64^{\circ} 1'.6$. The bright lines $\text{H}\gamma$ and $\text{H}\delta$ are seen on a continuous spectrum. Magn. 12-13.
- 16 45.1b. The spectrum is of Class Mb, having the lines $\text{H}\gamma$ and $\text{H}\delta$ equally bright. The line $\text{H}\zeta$ is also bright, with about 0.2 of the intensity of $\text{H}\delta$.
- 17 2.0. This star is C. DM. $-61^{\circ} 5736$, and is not contained in the Cape Durchmusterung. The range of variation is from magn. 11.7 to 13.3.
- 17 19.0. The position for 1875 is R. A. $17^{\text{h}} 17^{\text{m}} 9^{\text{s}}$, Dec. $-44^{\circ} 4'.5$. The bright lines $\text{H}\epsilon$, $\text{H}\delta$, $\text{H}\gamma$, $\text{H}\beta$, 4959, and 5007 are present. $\text{H}\beta$ and 5007 are the strongest. The image is stellar on chart plates.
- 17 20.3. The position for 1875 is R. A. $17^{\text{h}} 18^{\text{m}} 29^{\text{s}}$, Dec. $-46^{\circ} 48'.8$. Owing to faintness, only the chief nebular lines at 4959 and 5007 are seen. The image is faint and nebulous on chart plates.
- 17 38.2. This spectrum is already known as Peculiar, and having bright hydrogen lines. On a photograph taken with the 8-inch Bache Telescope, and having very narrow spectra, so that the violet end of the spectrum is well shown, a wide bright band is situated at 3728. On this plate the spectrum resembles that of the planetary nebula $-12^{\circ} 1172$, at R. A. $5^{\text{h}} 22^{\text{m}} 8^{\text{s}}$, Dec. $-12^{\circ} 46'$, except that the nebular lines N_1 and N_2 are not seen. The image is stellar on chart plates.
- 17 56.4. The position for 1875 is R. A. $17^{\text{h}} 54^{\text{m}} 31^{\text{s}}$, Dec. $-47^{\circ} 13'.9$. A star of the fourteenth magnitude follows 1^{r} , in the same approximate declination. The spectrum is of Class Mb, having the line $\text{H}\delta$ bright. The range of variation is from magn. 11.0 to <14 .
- 18 9.7. This spectrum is already known as Peculiar and having bright hydrogen lines. A photograph taken with the 24-inch Bruce Telescope shows also two faint emission lines which appear to be the chief nebular lines at 4959 and 5007. Thus, as in the case of the spectrum of $-46^{\circ} 11816$, R. A. $17^{\text{h}} 38^{\text{m}} 2^{\text{s}}$, Dec. $-46^{\circ} 3'$, described above, this object seems to be allied to the gaseous nebulae.
- 18 14.6. The position for 1875 is R. A. $18^{\text{h}} 12^{\text{m}} 48^{\text{s}}$, Dec. $-44^{\circ} 57'.2$. The spectrum is faint, but appears to be of Class Ma. The lines $\text{H}\gamma$ and $\text{H}\delta$ are nearly equally bright. The range of variation is from 11.9 to <14 .

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| <p><i>h. m.</i></p> <p>18 22.7. The position for 1875 is R. A. $18^{\text{h}} 21^{\text{m}} 6^{\text{s}}$, Dec. $-31^{\circ} 34'.5$. The lines $H\delta$, $H\gamma$, $H\beta$, 4959 and 5007 are bright. The image is stellar on chart plates.</p> <p>18 27.5. Variability discovered by Innes and announced in Circular 31, 242 of the Union Observatory. The spectrum is of Class Mb, having the line $H\delta$ 1.5 as bright as $H\gamma$.</p> <p>18 40.7. The spectrum is of well-marked intensity but no bright lines are seen. The range of variation is from magn. 9.0 to <12. The class is given incorrectly in H.A. 55, 23 as F.</p> <p>18 48.6. Also C.P.D. $-49^{\circ} 10791$, magn. 9.4. The spectrum is of Class Ma, having the lines $H\gamma$ and $H\delta$ nearly equally bright. The range of variation is from magn. 10.0 to <12.8.</p> <p>18 49.1. On Plate B 39499, this object was erroneously classified N, and was so announced in H. C. 196. The spectrum is near the edge of that plate, and only</p> | <p><i>h. m.</i></p> <p>one wide bright band is seen. A photograph taken with the 24-inch Telescope shows the bright lines, $H\delta$, $H\gamma$, $H\beta$, 4959 and 5007, of which the last is the strongest. The image is slightly hazy on chart plates.</p> <p>18 54.0. Announced in 1881 by Vogel to be of Type IV. Not previously confirmed photographically.</p> <p>19 1.6. The spectrum is of Class Mb, having the line $H\delta$ 3 times as bright as $H\gamma$. The range of variation is from magn. 10.4 to <13.5.</p> <p>19 20.3. The spectrum is of Class Mb, having the lines $H\gamma$ and $H\delta$ nearly equally bright. The range of variation is from magn. 11.0 to 14.</p> <p>19 34.5. The position for 1875 is R. A. $19^{\text{h}} 32^{\text{m}} 43^{\text{s}}$, Dec. $-44^{\circ} 53'.7$. A star of the thirteenth magnitude follows $4'$, in nearly the same declination. The spectrum has the line $H\delta$ twice as bright as $H\gamma$. The range of variation is from magn. 12.5 to <15.0.</p> |
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and 1899, gave no trace of emission. Photographs taken by Perrine in 1918 showed all lines dark, and recent plates received from Arequipa, prove that in 1920 the same was true. The star p Carinae, R. A. $10^{\text{h}} 28^{\text{m}}.5$, Dec. $-61^{\circ} 11'$, magn. 3.58, had conspicuous bright hydrogen lines, $H\beta$ and $H\gamma$, on 10 photographs taken between 1894 and 1897. Photographs taken by Perrine in 1918 showed that the bright lines had disappeared, which is confirmed by photographs taken at Arequipa in June, 1920.

ANNIE J. CANNON.

MARCH 23, 1921.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 225.

FIFTY-ONE NEW VARIABLE STARS.

A systematic comparison of photographs of the Milky Way, taken with the 1-inch Cooke Telescope, for the purpose of detecting new stars, has been carried on at this Observatory for the past two years. Besides the discovery of eight novae, as already announced in the Bulletins, a number of new variable stars have been found, several of which have been included in recent Circulars. The others are given in Table I, together with a few which have been found during various other photographic investigations. All suspected objects have been omitted. The variation of all the stars included in this Table has been confirmed by Miss Cannon or Miss Leavitt. The form of the Table is the same as that of Table I in H. C. 201. The ninth column gives the most probable class to which the variable belongs as determined by the observations already made. The Remarks contain additional facts, including the class of spectrum for all stars included in the Henry Draper Catalogue, and also for a few fainter stars. Attention may be called to the peculiarities of the variables, 044930b, and 065911, which are described in the Remarks.

TABLE I.

FIFTY-ONE NEW VARIABLE STARS.

Des.	H. V.	Constellation.	DM.	R.A. 1900.	Dec. 1900.	Bright.	Faint.	Class.	Discoverer.
				h. m. s.	° ' "				
001973	3549	Cepheus	..	0 19 17	+73 22.0	10.3	12.0	IV	J. C. Mackie
012360	3550	Cassiopeia	246	1 23 0	+60 27.4	9.4	10.7	V	J. C. Mackie
015427	3551	Triangulum	318	1 54 52	+27 24.0	9.1	10.9	V	A. D. Walker
034238	3552	Perseus	811	3 42 57	+38 39.5	9.0	10.5	V	M. D. Applegate
040246	3553	Perseus	..	4 2 17	+46 18.6	11.0	12.2	IV?	J. C. Mackie
044930b	3554	Auriga	741	4 49 23	+30 24.0	7.0	8.9	III	M. D. Applegate
051950	3555	Auriga	..	5 19 15	+50 1.6	10.6	<13.6	..	M. D. Applegate
052238	3556	Auriga	1168	5 22 6	+38 58.0	11.0	12.1	IV	M. D. Applegate

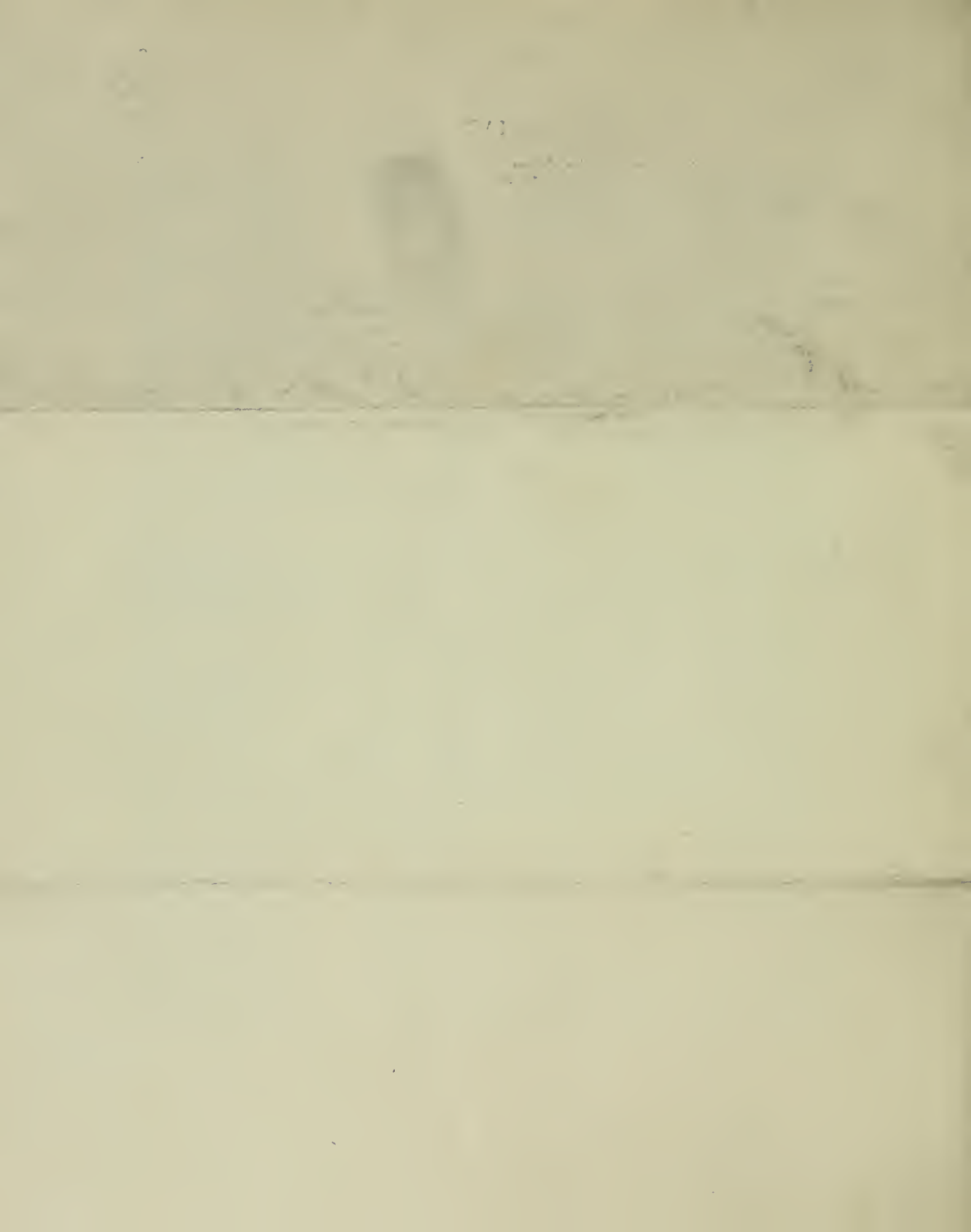
Des.	H. V.	Constellation.	DM.	R. A. 1900.	Dec. 1900.	Bright.	Faint.	Class.	Discoverer.
				<i>h. m. s.</i>	<i>° ' "</i>				
053004h	3557	Orion	..	5 30 45	- 4 28.8	13.6	15.3	III?	M. D. Applegate
053205b	3558	Orion	..	5 32 32	- 5 27.3	15.4	16.3	..	M. D. Applegate
060623	3559	Gemini	..	6 6 0	+23 31.6	9.7	10.5	..	J. C. Mackie
060620	3560	Lepus	1314	6 6 40	-20 11.5	9.2	10.3	V	I. E. Woods
063201	3561	Monoceros	..	6 32 27	- 1 18.3	9.6	<13.5	II	I. E. Woods
063832	3562	Gemini	1393	6 38 52	+32 24.9	10.3	11.2	IV?	J. C. Mackie
064537	3563	Puppis	3101	6 45 30	-37 9.7	9.5	10.5	..	I. E. Woods
064601	3564	Monoceros	..	6 46 25	- 1 15.0	10.6	11.8	IV	A. D. Walker
065911	3565	Canis Major	1760	6 59 2	-11 23.7	8.9	11.0	III	A. D. Walker
072005	3566	Monoceros	..	7 20 46	- 5 38.9	8.4	<13.2	II	I. E. Woods
074802	3567	Monoceros	2331	7 48 18	- 2 46.7	9.0	10.9	V	M. D. Applegate
075343	3568	Puppis	..	7 52 58	-43 52.6	9.2	<13.6	II	I. E. Woods
081213	3569	Puppis	..	8 12 37	-13 29.8	9.5	<13.1	II?	I. E. Woods
081542	3570	Puppis	4112	8 15 25	-42 26.4	9.3	10.3	..	M. D. Applegate
082509	3571	Hydra	..	8 25 2	- 9 4.1	10.7	<13.6	V	J. C. Mackie
084934	3572	Pyxis	5361	8 49 26	-34 26.2	8.6	11.0	III?	M. D. Applegate
090908	3573	Hydra	..	9 8 58	- 8 54.4	9.9	11.3	..	I. E. Woods
093139	3574	Antlia	5653	9 31 38	-39 27.1	9.3	10.9	..	M. D. Applegate
095727	3575	Leo	..	9 57 0	+27 10.6	11.4	<15.4	II	M. Harwood
102059	3576	Carina	2101	10 20 54	-59 40.9	8.8	10.1	..	I. E. Woods
105060	3577	Carina	2370	10 50 3	-60 33.6	9.6	11.0	..	M. D. Applegate
123053	3578	Centaurus	5714	12 30 32	-53 3.0	9.8	10.7	..	I. E. Woods
131016	3579	Virgo	3627	13 10 1	-16 56.8	9.0	<12.1	V	I. E. Woods
142043	3580	Lupus	9051	14 19 58	-43 41.8	10.4	11.8	..	I. E. Woods
145534	3581	Centaurus	10231	14 54 59	-34 5.1	10.4	<13.5	..	I. E. Woods
155240	3582	Lupus	..	15 52 43	-40 4.9	10.6	12.1	..	I. E. Woods
161931	3583	Corona	2847	16 19 9	+31 3.5	9.9	11.0	IV?	J. C. Mackie
162754	3584	Ara	7757	16 27 20	-54 32.6	10.1	<11.9	V	I. E. Woods
174058	3585	Pavo	..	17 40 7	-58 42.4	10.5	<13.5	II	I. E. Woods
174028	3586	Sagittarius	13577	17 40 46	-28 7.1	9.6	10.6	IV	I. E. Woods
174734c	3587	Scorpius	..	17 47 32	-34 19.2	12.3	15.2	II	M. D. Applegate
182621	3588	Hercules	3459	18 26 2	+21 47.6	7.4	9.0	IV	M. D. Applegate
184520	3589	Hercules	3950	18 45 43	+20 36.4	9.5	11.0	V	M. D. Applegate
193746	3590	Cygnus	2753	19 37 54	+46 32.7	9.3	10.4	..	J. C. Mackie
194044	3591	Sagittarius	..	19 40 14	-44 42.9	10.5	<13.5	..	I. E. Woods
194500	3592	Aquila	..	19 45 53	- 0 50.5	13.2	14.9	..	M. D. Applegate
194727	3593	Vulpecula	3536	19 47 25	+27 11.9	7.7	9.6	IV?	J. C. Mackie
200033	3594	Cygnus	1718	20 0 37	+33 49.6	8.9	10.7	IV	J. C. Mackie
211546	3595	Cygnus	3267	21 15 21	+46 35.1	9.2	10.8	III?	J. C. Mackie
213822	3596	Pegasus	4603	21 38 9	+22 0.9	10.0	10.9	..	J. C. Mackie
225134	3597	Lacerta	4794	22 51 19	+34 39.6	9.5	11.0	..	M. D. Applegate
233647	3598	Andromeda	4128	23 36 35	+47 2.5	10.3	11.4	IV	M. D. Applegate
233724	3599	Pegasus	..	23 37 14	+24 22.2	11.4	12.2	IV	M. D. Applegate

REMARKS.

012360. The spectrum is of an early division of Class B. Two photographs taken on October 20, 1919, 14^h 53^m and 15^h 53^m, G.M.T. show the star at minimum, but at 17^h 4^m on the same night, the light had commenced to increase. The star was bright on November 18 and 24, 1919.
015427. H. D. 12211. Spectrum A0.
034238. The spectrum is of Class A.
- 044930b. H. D. 31293. Spectrum A0. To confirm the variation, an examination was made by Miss Applegate of 150 photographs, taken between 1914 and 1921. Only three minima were found. The star was faint from November 26 to 28, 1914, from March 4 to April 8, 1916, and from September 14 to 19, 1917. The variation appears to be irregular, although the class of spectrum suggests a variable of the Algol type. This star precedes the known variable, SU Aurigae, 13^h 6, and is south 0^h 4.
053004. Bond No. 773 in the Orion Nebula. The variation was found while observing the variable stars in the nebula.
053205. Found while observing variables in the Orion Nebula.
060620. The star is faint on 6 out of 50 photographs examined. Spectrum, Class A.
065911. H. D. 53179. Spectrum Bp. The light of this star has been measured by Miss Walker on 275 photographs taken between 1899 and 1921. The variation is irregular and the light curve bears some resemblance to that of R Coronae Borealis. During long periods the light is constant or subject only to minor fluctuations. At least two deep minima have occurred since 1899. The first lasted from February 1908 to April 1909. The last minimum occurred in November, 1920, magn. 11.4, and maximum light was not reached until about the middle of April, 1921. The spectrum has the lines H β and H γ bright and contains numerous dark lines, some of which are due to helium. The spectrum during minimum is shown on several plates. It is faint, but H γ appears to remain bright during that phase.
074802. The spectrum is of Class B8 on a photograph taken December 23, 1895. The variation is probably of the Algol type.
075343. A period of 338^d satisfies the observations already made.
081542. H. D. 70196. Spectrum F0. The period is short.
082509. The star is faint on about ten plates out of 150 which were examined.
084934. H. D. 76181. Spectrum K2.
093133. H. D. 83199. Spectrum Mc.
095727. This was a comparison star for measuring Eros on plates taken in 1900. Period about 307^d, determined by Miss Harwood.
102059. H. D. 90382. Spectrum Mb.
105060. H. D. 94599. Spectrum Ma.
123053. H. D. 109576. Spectrum Mb.
131016. H. D. 115122. Spectrum A2.
142043. H. D. 126387. Spectrum Mb.
145534. A star of the twelfth magnitude follows the variable 5^h 6, south 0^h 8.
162754. The spectrum is of Class A, and probably A0.
174023. Spectrum F5.
- 174734c. The variation was found during observations of 174734b, Nova Scorpii, No. 2, which preceded 4^h, and was south 0^h 5. Estimates of the magnitude on 180 photographs by Miss Applegate show that the period is probably long.
182621. Spectrum F8.
184520. Spectrum F.
194500. The variation was found during a search for Asteroid 1903 NF.
194727. Spectrum K0 at maximum, changing to K5 or Ma at minimum.
200033. The period is probably short. Spectrum K5?
211546. Spectrum K2.
213822. Spectrum Mb.
225134. Spectrum K2.
233724. The variation was found while measuring Eros on photographs taken in 1914.

S. I. BAILEY,
Acting Director.

MAY 2, 1921.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 226.

ON THE RELATION OF SPECTRAL TYPE TO MAGNITUDE.

BY HARLOW SHAPLEY AND ANNIE J. CANNON.

THE total number of stars in the Henry Draper Catalogue will be about 225,000. Several hundred objects have been placed in the less common classes P, O, R, N, Md, or their spectra were designated as "Peculiar" or "Continuous." More than ninety-nine per cent of all the stars, however, have been assigned to the ordinary classes B, A, F, G, K, and M.

The numbers of stars of each spectral class for successive intervals of visual magnitude are given in Table I, which is based on the manuscript

TABLE I.
NUMBERS OF STARS FOR EACH SPECTRAL CLASS AND MAGNITUDE INTERVAL.

Spectral Class.	Intervals of Visual Magnitude.								All Magnitudes.
	Br. to 6.25	6.26 to 6.75	6.76 to 7.25	7.26 to 7.75	7.76 to 8.25	8.26 to 8.75	8.76 to 9.25	9.26 to Ft.	
B0-5	719	265	302	325	450	482	483	541	3,567
B8	274	180	258	334	558	714	872	1,205	4,395
B9	280	344	520	584	1,024	1,344	1,736	2,576	8,408
A0	736	536	864	1,424	2,760	4,864	6,152	13,480	30,816
A2,3	728	400	784	1,080	2,216	3,526	4,240	7,656	20,640
A5	248	88	192	272	552	856	1,040	1,816	5,064
F0	288	296	392	712	1,520	2,048	1,976	2,568	9,800
F2	144	136	376	480	840	1,400	1,368	1,512	6,256
F5	280	184	544	592	1,904	2,672	3,152	4,200	13,528
F8	160	80	320	712	1,216	2,488	3,136	5,920	14,032
G0	216	264	408	592	1,304	2,560	4,376	9,272	18,992
G5	440	280	656	1,080	2,792	4,328	5,384	9,104	24,064
K0	1,312	1,112	1,544	2,536	5,000	6,976	7,640	9,272	35,392
K2	232	120	448	920	2,288	2,912	3,008	3,824	13,752
K5	280	184	328	672	1,368	2,296	2,504	2,416	10,048
Ma	171	114	174	309	436	518	462	483	2,667
Mb,c	87	39	76	97	156	173	213	308	1,149
Total	6,595	4,622	8,186	12,721	26,384	40,167	47,742	76,153	222,570

of the Henry Draper Catalogue. The additions and revisions that have intervened between the first manuscript and the printed volumes are statistically unimportant. In preparing Table I, all stars of Class M and Class B (except B9) were collected into separate catalogues and arranged in the order of brightness. For the intermediate classes of spectrum, the material from the catalogue was classified with respect to magnitude for the first five minutes of each forty minutes in right ascension, beginning with R.A. $0^h 20^m$; the results were then multiplied by eight. The tabulated numbers for these intermediate classes and for the totals are therefore not numerically exact, but they are sufficiently accurate for the present statistical treatment.

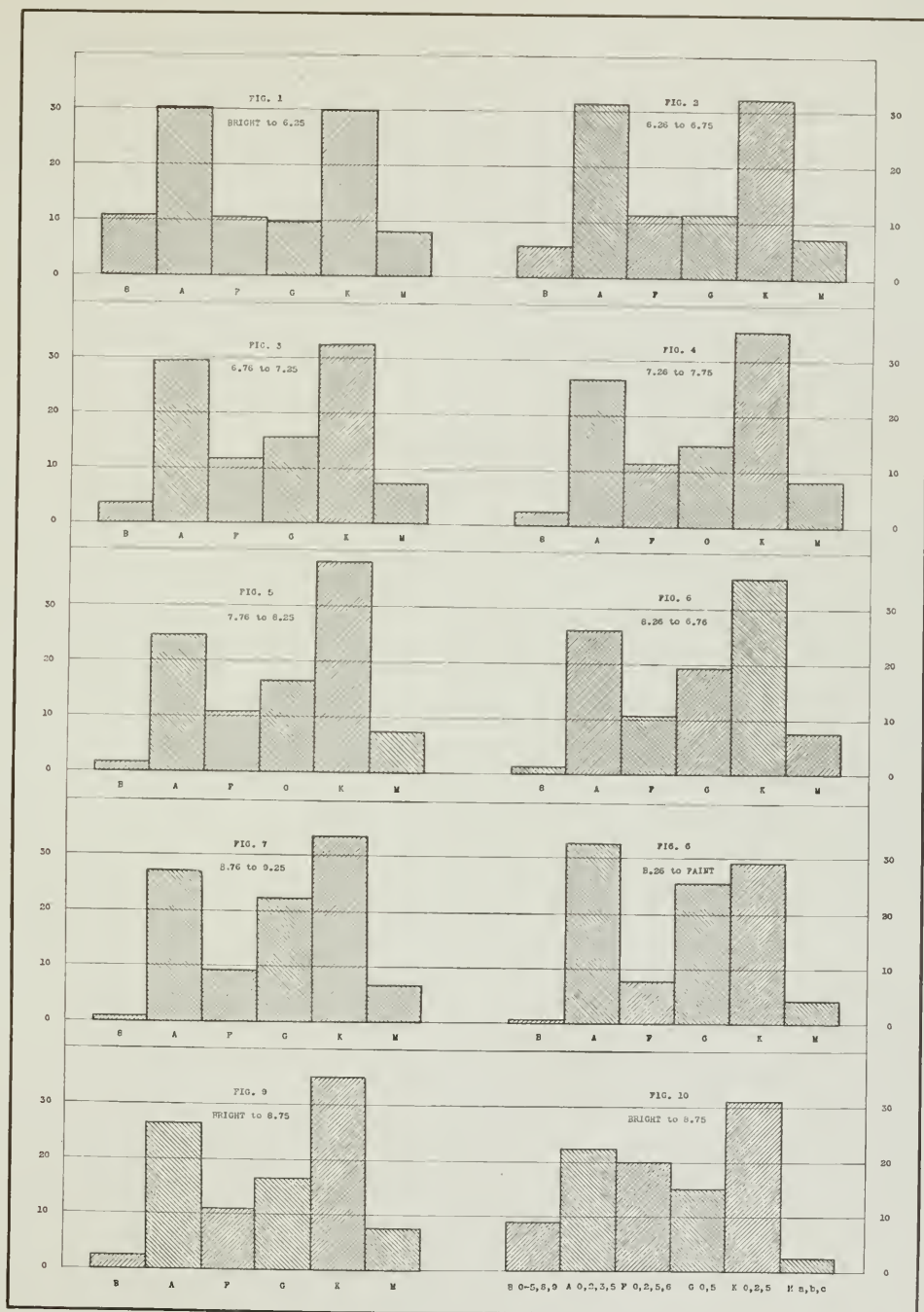
The second column of Table I, containing the stars brighter than magnitude 6.25, may be considered as representing the distribution of naked eye stars among the various spectral classes. About sixty per cent of these brighter stars are earlier than the Sun in spectrum, but the class K0 contains nearly twice as many as any other individual class.

In making Table II from the numbers of Table I, the classes of spectrum were grouped into larger classes, which, for convenience, may be designated Spectral Divisions:

Division	Classes
B.....	B0, B1, B2, B3, B5
A.....	B8, B9, A0, A2, A3
F.....	A5, F0, F2
G.....	F5, F8, G0
K.....	G5, K0, K2
M.....	K5, Ma, Mb, Mc

The above divisions are arbitrarily chosen and are not strictly uniform in extent with respect either to range of color index or effective surface temperatures, or with respect to any other single argument; they closely agree, however, with the grouping commonly adopted for statistical investigations involving spectral type.

The tabulated quantities for each division in Table II are the total numbers of stars brighter than the magnitude limits given at the heads of the columns. If the stellar density for any spectral type were uniform throughout space, the numbers in Table II should double with every decrease of half a magnitude in brightness. This condition, as is well known from earlier investigations, does not hold for any of the spectral divisions; its conspicuous failure below magnitude 8.25 is due in part to the incompleteness of the catalogue for faint stars. The nearest approach to the theoretical values for uniform density occurs in Division G.



SPECTRAL TYPE AND MAGNITUDE.

TABLE II.

NUMBERS OF STARS TO SUCCESSIVE MAGNITUDE LIMITS FOR EACH SPECTRAL DIVISION.

Spectral Division.	Visual Magnitudes Brighter Than						
	6.25	6.75	7.25	7.75	8.25	8.75	9.25
B	719	984	1,286	1,611	2,061	2,543	3,026
A	2,018	3,478	5,904	9,326	15,884	26,342	39,342
F	680	1,200	2,160	3,624	6,536	10,840	15,224
G	656	1,184	2,456	4,352	8,776	16,496	27,160
K	1,984	3,496	6,144	10,680	20,760	34,976	51,008
M	538	875	1,453	2,531	4,491	7,478	10,657
Total	6,595	11,217	19,403	32,124	58,508	98,675	146,417

For the southern sky the catalogue appears to be practically complete to magnitude 8.75; for the northern sky the limit is probably half a magnitude brighter. The occasional omissions of stars brighter than these limits are believed to be unrelated to spectral type and therefore not significant in the inter-comparison of the proportion of stars for various classes, as in Table III below. But the omissions directly affect the relation of number of stars to magnitude for any given spectral class, and the material in Table II has little value in determining stellar density below the eight magnitude.

Table III shows the relative frequency of the various spectral divisions for different intervals of visual magnitude. It illustrates in what proportions the

TABLE III.

FREQUENCY OF SPECTRAL DIVISIONS FOR SUCCESSIVE MAGNITUDE INTERVALS.

Spectral Division.	Intervals of Visual Magnitude.									
	Br. to 6.25	6.26 to 6.75	6.76 to 7.25	7.26 to 7.75	7.76 to 8.25	8.26 to 8.75	8.76 to 9.25	9.26 to Ft.	All Mag.	Br. to 8.75
B	10.9	5.7	3.7	2.6	1.7	1.2	1.0	0.7	1.6	2.5
A	30.5	31.6	29.6	26.9	24.9	26.0	27.2	32.7	28.9	26.7
F	10.4	11.3	11.6	11.5	11.0	10.7	9.2	7.7	9.5	11.0
G	9.9	11.4	15.5	15.0	16.8	19.2	22.3	25.5	20.9	16.7
K	30.1	32.7	32.4	35.6	38.2	35.5	33.6	29.2	32.9	35.4
M	8.1	7.3	7.0	8.5	7.4	7.3	6.7	4.2	6.2	7.6
B, A, F	51.8	48.6	45.1	41.0	37.6	38.0	37.4	41.2	40.0	40.3
G, K, M	48.2	51.4	54.9	59.0	62.4	62.0	62.6	58.8	60.0	59.7

stars are mixed when analyzed on the basis of apparent brightness. The tabulated quantities for a given magnitude interval are expressed as percentages of the total number of stars in that interval.

A striking phenomenon brought out by Table III is the increase in the relative number of G stars (F5, F8, G0) with decreasing brightness. Also Class G5 separately shows a similar increase in relative number. The numbers for the Divisions A, F, K, and M show little change with decreasing brightness down to the ninth magnitude. For Division B the well known decrease of relative number with decreasing brightness is clearly shown.

Figures 1 to 9, based upon the percentages in successive columns of Table III, illustrate the principal results of this statistical investigation. In some respects the present values are similar to those obtained thirty years ago by Professor E. C. Pickering in discussing the Draper Catalogue, *Harvard Annals*, 26, 154, but the great preponderance of Class A stars then found has now disappeared in the gains for Classes B and F; the present discussion is based upon twenty times as much material.

In classifying the spectra of stars fainter than magnitude 8.75, there may have been a selection favoring certain classes. If that is the case, the percentages for "all magnitudes" in Table III will be affected and cannot be taken as truly representing the frequency of spectral type down to the faintest magnitudes included in the Henry Draper Catalogue. In the last column, therefore, the percentages are given only for stars brighter than magnitude 8.75, and the corresponding diagram in Fig. 9, may be taken as the best representation now available of the distribution of the various spectra among the brighter stars. In later discussions the relation of spectral class to galactic coordinates will be considered.

Figure 10 is based upon the same material as Fig. 9, but with the spectral classes grouped in another manner.

JULY 30, 1921.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 227.

VARIABLE STARS. PREDICTED MAXIMA AND MINIMA IN 1922.

By LEON CAMPBELL.

PREDICTED dates of maxima and minima for variable stars of long period are given in Table I. The successive columns give the designation number, the name, and the predicted dates.

TABLE I.
PREDICTED MAXIMA AND MINIMA.

Des.	Name.	1922		Des.	Name.	1922		Des.	Name.	1922	
		Max.	Min.			Max.	Min.			Max.	Min.
000339	V Sculptoris	m. d.	m. d.	011712	U Piscium	m. d.	m. d.	032043	Y Persei	m. d.	m. d.
001032	S "	4 22	10 12	"	"	3 29	6 10	"	"	7 14	3 26
001046	X Androm.	12 23	7 10	"	"	9 18	11 30	"	"	...	12 1
001726	T "	11 15	6 5	012350	RZ Persei	4 17	11 4	032335	R "	2 24	6 14
001755	T Cassiop.	8 29	4 8	012502	R Piscium	6 4	1 1	"	"	9 22	...
001838	R Androm.	5 12	12 29	"	"	...	12 11	034625	U Eridani	7 4	4 15
001862	S Tucanae	2 14	9 22	013238	RU Androm.	4 7	1 1	"	"	...	12 11
"	"	3 31	8 13	"	"	12 7	9 2	035124	T "	5 1	8 27
001909	S Ceti	11 26	...	013338	Y "	5 25	3 12	040725	W "	1 1	8 22
"	"	1 15	7 6	"	"	12 30	10 16	042209	R Tauri	8 23	5 10
002438a	T Sculptoris	12 1	...	014958	X Cassiop.	3 20	8 17	042215	W "	8 25	4 21
"	"	5 9	1 27	015354	U Persei	2 2	9 22	042309	S "	6 7	1 1
"	"	11 27	8 17	"	"	12 19	...	"	"	...	12 31
002546	T Phoenicis	1 5	6 4	015912	S Arietis	8 6	3 29	043065	T Camelop.	6 14	12 26
"	"	10 12	...	021024	R "	5 1	1 31	043208	RX Tauri	6 14	1 5
003179	Y Cephei	4 21	10 28	"	"	11 3	8 5	"	"	...	12 11
004047	U Cassiop.	8 15	4 11	021143a	W Androm.	10 17	4 30	043263	R Reticuli	9 13	5 21
004132	RW Androm.	8 8	1 25	021281	Z Cephei	5 8	9 22	043274	X Camelop.	1 30	4 7
004435	V "	5 13	1 8	021403	o Ceti	5 5	1 1	"	"	6 22	8 28
"	"	...	9 28	"	"	...	11 27	"	"	11 12	...
004435	X Sculptoris	2 14	6 26	022000	R "	1 1	3 30	043738	R Caeli	2 2	9 30
"	"	10 24	...	"	"	6 17	9 13	044349	R Pictoris	5 13	3 16
004533	RR Androm.	2 24	9 22	"	"	12 1	...	"	"	10 25	8 28
004746a	RV Cassiop.	1 20	8 25	022150	RR Persei	2 18	11 24	044617	V Tauri	1 15	4 15
"	"	12 17	...	022426	R Fornacis	8 25	2 14	"	"	7 4	10 2
004958	W "	1 29	8 27	022813	U Ceti	3 28	7 18	"	"	12 22	...
005475	U Tucanae	8 7	4 13	"	"	11 19	...	045307	R Orionis	7 13	2 13
"	"	...	12 27	022980	RR Cephei	6 19	1 1	045514	R Leporis	9 10	1 31
010102	Z Ceti	4 18	1 15	023133	R Trianguli	1 30	6 18	050003	V Orionis	1 12	5 9
"	"	10 20	7 19	"	"	10 24	...	"	"	10 6	...
010630	U Sculptoris	1 13	8 21	025050	R Horologii	7 9	1 30	050022	T Leporis	2 6	8 10
"	"	12 7	...	025751	T "	1 1	4 23	050848	S Pictoris	11 20	6 23
010940	U Androm.	5 16	1 31	"	"	8 9	11 29	050953	R Aurigae	11 20	4 4
011041	UZ "	4 25	10 27	030514	U Arietis	5 27	12 11	051247	T Pictoris	7 12	4 5
011208	S Piscium	10 6	4 29	031401	X Ceti	2 8	5 19	"	"	...	10 22
011272	S Cassiop.	...	12 1	"	"	8 3	11 11	051533	T Columbae	6 16	3 11

Des.	Name.	1922		Des.	Name.	1922		Des.	Name.	1922	
		Max.	Min.			Max.	Min.			Max.	Min.
051533	T Columbae	m. d.	m. d.	081617	V Cancri	m. d.	m. d.	122532	T Can. Ven.	m. d.	m. d.
052036	W Aurigae	5 1	1 1	" "	" "	10 22	...	122803	Y Virginis	2 8	6 7
"	"	...	10 4	082476	R Chamael.	8 23	4 16	"	"	9 15	...
052404	S Orionis	8 26	1 28	083019	U Caneri	7 24	2 19	122854	U Centauri	6 7	2 18
053068	S Camelop.	1 23	7 2	083350	X Urs. Maj.	8 7	4 2	"	"	...	9 25
"	"	12 17	...	"	"	...	12 5	123160	T Urs. Maj.	9 6	5 19
053531	U Aurigae	5 21	12 31	084803	S Hydrae	4 15	8 15	123307	R Virginis	1 15	3 26
054331	S Columbae	9 4	5 1	"	"	12 27	...	"	"	6 9	8 18
054615a	Z Tauri	2 24	11 7	085008	T "	4 14	9 20	"	"	11 1	...
054629	R Columbae	9 14	5 8	090024	S Pyxidis	4 1	1 1	123459	RS Urs. Maj.	5 24	10 20
054920	U Orionis	8 8	3 11	"	"	10 26	7 28	123961	S " "	3 7	7 11
054974	V Camelop.	...	9 15	090425	W Caneri	12 21	7 21	"	"	10 19	...
055353	Z Aurigae	4 5	2 4	091868	RW Carinae	10 16	6 16	124204	RU Virginis	...	5 15
"	"	7 24	5 25	092551	Y Velorum	...	8 20	124606	U "	7 11	3 28
"	"	11 11	9 12	092962	R Carinae	3 13	10 28	130212	RV "	9 27	6 4
"	"	...	12 31	093014	X Hydrae	8 23	5 5	131283	U Octantis	3 12	8 15
055686	R Octantis	11 7	4 13	093178	Y Draconis	9 2	5 15	132202	V Virginis	7 9	4 15
060450	X Aurigae	3 27	6 2	093934	R Leo. Min.	3 16	10 12	132422	R Hydrae	...	7 14
"	"	9 4	11 10	094023	RR Hydrae	10 21	5 12	132706	S Virginis	3 3	8 30
061647	V "	8 27	2 26	094211	R Leonis	9 26	6 6	133155	RV Centauri	3 16	10 2
061702	V Monoc.	5 7	11 5	094953	Z Velorum	8 10	2 1	133273	T Urs. Min.	6 24	3 30
063159	U Lynceis	10 12	4 25	095421	V Leonis	9 8	5 8	133633	T Centauri	1 5	2 22
063558	S "	8 3	4 5	095563	RV Carinae	4 25	12 11	"	"	4 5	5 23
064030	X Gemin.	4 27	9 16	100661	S "	3 1	5 9	"	"	7 4	8 21
065111	Y Monoc.	2 24	6 14	"	"	7 28	10 5	"	"	10 2	11 19
"	"	10 7	...	"	"	12 24	...	"	"	12 31	...
065355	R Lynceis	6 23	1 1	101058	Z Carinae	10 12	5 15	134236	RT "	5 23	1 13
070109	V Can. Min.	9 30	5 17	101153	W Velorum	8 23	2 24	"	"	...	9 18
070122a	R Gemin.	11 6	7 2	103270	RZ Carinae	5 27	2 16	134440	R Can. Ven.	4 19	9 14
070310	R Can. Min.	1 13	8 1	"	"	...	11 15	134536	RX Centauri	1 24	8 21
"	"	12 17	...	103769	R Urs. Maj.	7 21	2 26	"	"	...	12 19
070772	R Volantis	5 26	12 31	"	"	...	11 25	134677	T Apodis	2 13	7 22
071201	RR Monoc.	8 31	3 28	104620	V Hydrae	...	7 24	"	"	11 9	...
071713	V Gemin.	5 21	2 10	104628	RS "	9 20	4 23	135908	RR Virginis	3 16	7 22
"	"	...	11 13	104814	W Leonis	2 22	11 17	"	"	10 22	...
072708	S Can. Min.	6 2	11 1	110506	S "	3 14	6 4	140113	Z Bootis	2 28	8 26
072811	T Can. Min.	2 11	8 1	"	"	9 19	12 10	"	"	12 9	...
"	"	12 27	...	111661	RS Centauri	1 17	4 13	140512	Z Virginis	7 2	3 5
072820b	Z Puppis	7 13	1 1	"	"	7 2	9 26	140528	RU Hydrae	3 8	1 15
073173	S Volantis	11 15	5 28	"	"	12 15	...	140959	R Centauri	1 28	12 14
073508	U Can. Min.	12 1	5 15	114441	X "	2 3	8 11	141567	U Urs. Min.	4 12	10 6
073723	S Gemin.	1 27	7 12	"	"	12 14	...	141954	S Bootis	8 1	3 6
"	"	11 17	...	115058	W "	7 18	4 11	"	"	...	12 1
074241	W Puppis	4 15	2 16	"	"	...	10 31	142205	RS Virginis	4 8	12 1
"	"	8 14	9 25	115919	R Comae	6 21	1 27	142539	V Bootis	4 2	8 31
"	"	12 13	...	120012	SU Virginis	2 25	6 16	"	"	12 17	...
074323	T Gemin.	1 31	7 10	"	"	9 24	...	142584	R Camelop.	5 27	1 24
"	"	11 15	...	120905	T Virginis	8 27	3 25	"	"	...	10 20
075612	U Puppis	6 24	3 1	121418	R Corvi	4 17	10 8	143227	R Bootis	1 1	4 26
081112	R Cancr.	4 5	9 26	122001	SS Virginis	10 30	5 5	"	"	8 12	12 5

Des.	Name.	1922		Des.	Name.	1922		Des.	Name.	1922	
		Max.	Min.			Max.	Min.			Max.	Min.
143417	V Librae	m. d. 3 1	m. d. 8 23	161122a	R Scorpil	m. d. 6 22	m. d. 3 10	175111	RT Ophiuchi	m. d. ...	m. d. 8 5
"	"	11 11	...	"	"	...	10 20	175458a	T Draconis	28 9	2 20
144918	U Bootis	1 17	4 9	161122b	S Scorpil	4 4	1 18	175519	RY Herculis	2 4	6 8
"	"	7 13	10 3	"	"	9 28	7 14	"	"	9 14	...
145254	Y Lupi	1 2	10 6	161138	W Cor. Bor.	6 5	2 28	175654	V Draconis	1 1	5 8
150018	RT Librae	3 7	7 26	"	"	...	10 22	"	"	10 11	...
"	"	11 17	...	161607	W Ophiuchi	4 5	10 12	180363	R Pavonis	3 24	8 6
150519	T Librae	1 7	5 19	162112	V "	10 2	4 22	"	"	11 8	...
"	"	9 16	...	162119	U Herculis	1 18	9 25	180531	T Herculis	5 27	3 1
150605	Y "	2 11	8 7	162807	SS "	1 31	3 24	"	"	11 8	8 13
"	"	11 15	...	"	"	5 11	7 2	180565	W Draconis	5 28	2 17
151520	S "	5 5	2 6	"	"	8 19	10 10	180666	X "	2 15	7 15
"	"	11 13	8 17	"	"	11 27	...	"	"	11 13	...
151714	S Serpentis	8 21	3 24	162815	T Ophiuchi	4 16	10 12	181103	RY Ophiuchi	2 10	5 9
151731	S Cor. Bor.	1 16	9 3	162816	S "	2 18	7 30	"	"	7 14	10 10
151822	RS Librae	5 9	1 30	"	"	10 10	...	"	"	12 15	...
"	"	12 12	9 4	163137	W Herculis	5 11	1 1	181136	W Lyrae	1 12	4 29
152714	RU "	6 20	1 21	"	"	...	10 8	"	"	7 28	11 12
152849	R Normae	10 13	3 27	163266	R Draconis	4 11	8 27	182133	RV Sagittar.	8 1	2 13
153215	W Librae	1 30	5 25	"	"	12 13	...	"	"	...	12 29
"	"	8 23	...	164319	RR Ophiuchi	9 16	4 19	182224	SV Herculis	5 31	3 1
153378	S Urs. Min.	7 22	2 8	164715	S Herculis	1 13	6 30	"	"	...	10 27
"	"	...	12 29	"	"	11 17	...	182306	T Serpentis	3 10	8 28
153620a	U Librae	7 26	3 26	164844	RS Scorpil	9 6	3 29	183149	SV Draconis	7 24	4 13
"	"	...	11 7	165030	RR "	2 20	7 8	"	"	...	12 27
153654	T Normae	7 12	3 10	"	"	11 29	...	183225	RZ Herculis	2 14	9 5
"	"	...	11 9	165202	SS Ophiuchi	1 22	4 9	183308	X Ophiuchi	4 20	9 22
154536	X Cor. Bor.	7 14	2 14	"	"	7 8	9 23	184134	RY Lyrae	5 17	10 16
"	"	...	10 22	"	"	12 22	...	184243	RW "	10 28	6 30
154615	R Serpentis	2 21	10 26	165631	RV Herculis	5 8	2 3	185032	RX "	6 6	2 11
154639	V Cor. Bor.	11 17	6 12	"	"	11 28	8 26	"	"	...	10 16
154715	R Librae	8 17	5 9	165636	RT Scorpil	3 23	12 18	185634	Z Lyrae	9 2	4 25
154736	R Lupi	4 29	1 9	170215	R Ophiuchi	1 17	7 16	185737	RT "	6 23	2 3
"	"	12 19	8 31	170627	RT Herculis	2 7	7 27	"	"	...	10 10
155018	RR Librae	6 27	3 3	"	"	12 7	...	190108	R Aquilae	8 23	4 28
"	"	...	12 5	170833	RW Scorpil	2 19	10 22	190529a	V Lyrae	5 28	12 11
155229	Z Cor. Bor.	5 14	1 16	171401	Z Ophiuchi	2 11	8 12	190925	S "	5 17	...
"	"	...	9 12	171723	RS Herculis	5 8	1 26	190933	RS "	1 21	7 26
155823	RZ Scorpil	4 25	2 11	"	"	12 15	9 4	"	"	11 13	...
"	"	10 3	7 22	172586	S Octantis	3 5	8 11	190941	RU "	12 11	6 24
"	"	...	12 30	"	"	11 19	...	190967	U Draconis	2 7	7 12
160021	Z "	12 23	6 30	172809	RU Ophiuchi	6 23	3 18	"	"	12 22	...
160118	R Herculis	5 3	1 3	"	"	...	10 6	191007	W Aquilae	12 31	8 10
160210	U Serpentis	1 10	5 25	173543	RU Scorpil	12 15	5 10	191017	T Sagittarii	5 26	12 31
"	"	9 7	...	174135	SV Scorpil	6 28	3 5	191019	R "	6 23	2 13
160221a	X Scorpil	4 5	1 1	"	"	...	11 17	"	"	...	11 9
"	"	10 21	7 19	174162	W Pavonis	3 14	9 16	191124	TY "	3 5	7 18
160519	W Scorpil	7 20	3 30	"	"	12 21	...	191319	S "	4 10	8 5
"	"	...	11 7	174551	U Arae	5 13	1 15	"	"	11 27	...
160625	RU Herculis	...	11 7	"	"	12 23	8 27	191321	Z "	...	9 4

Des.	Name.	1922		Des.	Name.	1922		Des.	Name.	1922	
		Max.	Min.			Max.	Min.			Max.	Min.
191331	SW Sagittar.	8 31	5 4	203429	R Microsc.	1 19	4 8	220412	T Pegasi	6 13	12 1
191637	U Lyrae	11 22	4 6	"	"	6 7	8 28	220613	Y "	5 4	1 21
192928	TY Cygni	12 9	7 8	"	"	10 24	.	"	"	11 26	8 15
193311	RT Aquilae	9 3	5 1	203611	Y Delphini	1 12	11 8	220714	RS "	10 8	5 21
193449	R Cygni	4 29	...	203816	S "	2 21	7 16	221230	R Pis. Aust.	7 14	12 7
193509	RV Aquilae	5 10	1 14	"	"	11 25	...	221321	X Aquarii	5 30	11 4
"	"	12 15	8 21	203847	V Cygni	10 12	3 16	221938	T Gruis	2 16	4 25
193972	T Pavonis	1 17	6 12	203905	Y Aquarii	7 21	2 16	"	"	7 2	9 8
"	"	9 18	...	204016	T Delphini	1 6	6 25	"	"	11 15	...
194048	RT Cygni	2 12	5 20	"	"	12 3	...	221948	S "	11 5	6 16
"	"	8 21	11 26	204104	W Aquarii	4 8	11 7	222129	RV Pegasi	11 9	7 2
194348	TU Cygni	7 20	4 19	204215	U Capric.	2 6	5 9	222439	S Lacertae	5 2	1 18
"	"	...	11 23	"	"	8 27	11 27	"	"	...	9 12
194604	X Aquilae	2 12	8 31	204318	V Delphini	...	9 4	222867	R Indi	6 16	3 5
194632	x Cygni	9 28	4 21	204405	T Aquarii	5 5	1 26	"	"	...	10 7
194659	S Pavonis	12 31	7 4	"	"	11 24	8 17	223462	T Tucanae	4 7	8 16
194929	RR Sagittar.	2 17	8 21	204846	RZ Cygni	8 3	2 24	"	"	12 14	...
195142	RU "	5 14	1 27	204954	S Indi	...	8 8	223841	R Lacertae	6 24	1 25
"	"	...	9 26	205017	X Delphini	8 4	3 26	"	"	...	11 21
195202	RR Aquilae	6 29	1 20	"	"	...	12 31	225120	S Aquarii	1 5	5 25
195308	RS "	8 19	4 21	205627	RR Capric.	4 5	8 3	"	"	10 12	...
195849	Z Cygni	6 19	2 17	"	"	12 1	...	225914	RW Pegasi	5 12	2 2
"	"	...	1 7	205923	R Vulpec.	4 29	2 25	"	"	12 7	8 30
200212	SY Aquilae	3 29	10 16	"	"	9 13	7 12	230110	R "	2 27	10 6
200357	S Cygni	3 19	9 28	"	"	...	11 26	230759	V Cassiop.	2 12	6 20
200514	R Capric.	5 19	1 19	210124	V Capric.	1 1	5 5	"	"	9 30	...
"	"	...	12 29	"	"	10 8	...	231425	W Pegasi	1 31	7 26
200715a	S Aquilae	5 1	2 11	210129	TW Cygni	2 6	8 17	231508	S "	7 11	2 11
"	"	9 25	7 8	210221	X Capric.	1 6	4 3	"	"	...	12 25
"	"	...	12 2	"	"	8 12	11 7	232746	V Phoenicis	2 2	6 6
200747	R Telescopii	9 2	3 6	210382	X Cephei	...	10 15	"	"	10 11	...
200812	RU Aquilae	6 20	2 6	210516	Z Capric.	9 8	3 14	233335	ST Androm.	1 25	6 16
"	"	...	11 9	210812	R Equulei	4 17	8 17	"	"	12 1	...
200822	W Capric.	1 16	5 13	210868	T Cephei	5 7	11 5	233815	R Aquarii	1 22	8 30
"	"	8 12	12 7	210903	RR Aquarii	2 24	5 25	233956	Z Cassiop.	...	11 7
200906	Z Aquilae	4 13	2 12	"	"	8 23	11 21	235053	RR "	2 24	7 24
"	"	8 20	6 21	211614	X Pegasi	4 13	1 3	"	"	12 21	...
"	"	12 27	10 28	"	"	10 30	7 22	235150	R Phoenicis	2 24	7 14
200938	RS Cygni	12 21	5 25	211615	T Capric.	2 2	7 2	"	"	11 21	...
201008	R Delphini	7 3	2 28	"	"	10 29	...	235209	V Ceti	4 24	1 6
"	"	...	12 19	212030	S Microsc.	3 29	1 8	"	"	...	9 24
201130	SX Cygni	3 12	12 9	"	"	10 28	8 9	235265	R Tucanae	4 5	9 12
201139	RT Sagittar.	2 22	8 31	213678	S Cephei	11 15	1 31	235350	R Cassiop.	12 30	7 16
201647	U Cygni	5 6	12 2	214024	RR Pegasi	3 1	8 3	235525	Z Pegasi	4 15	9 22
202240	U Microsc.	3 31	11 17	"	"	11 21	...	235715	W Ceti	3 12	10 4
202622	RU Capric.	7 3	3 7	214247	R Gruis	11 15	7 5	235855	Y Cassiop.	1 31	10 24
202817	Z Delphini	4 24	10 18	215605	V Pegasi	2 17	8 16	235939	SV Androm.	7 12	3 17
202954	ST Cygni	3 31	9 12	"	"	12 17	...				

HARVARD COLLEGE OBSERVATORY

CIRCULAR 228

THE DISTANCES OF FIFTY STARS DETERMINED FROM OBJECTIVE PRISM SPECTRA

BY HARLOW SHAPLEY AND BERTIL LINDBLAD

SPECTRA made with a small telescope and an objective prism were used at Mount Wilson five years ago for the determination of the luminosities and distances of stars and the results were reported in a short paper on the spectra of Cepheid variables.¹ For the further study of this problem, Professor E. C. Pickering kindly submitted from the Harvard collection a selection of photographs of various spectral classes; the plates were found to be satisfactory for the investigation of absolute brightness.

The dispersion used for Harvard photographs of the brighter stars is sufficient to permit the estimate of luminosity through the use of the special spectral criteria discovered and used for slit spectrograms by the Mount Wilson observers. Moreover, within the last few years several other characteristics of spectra and magnitudes have been found to serve as an index of absolute brightness,² and with these criteria we shall be able to extend the usefulness of objective prism spectra to fainter stars. In particular, Lindblad's unpublished results, connecting the intensity of the "cyanogen" bands with luminosity for certain types of stars,³ promises to be of much utility in the analysis of existing Harvard material.

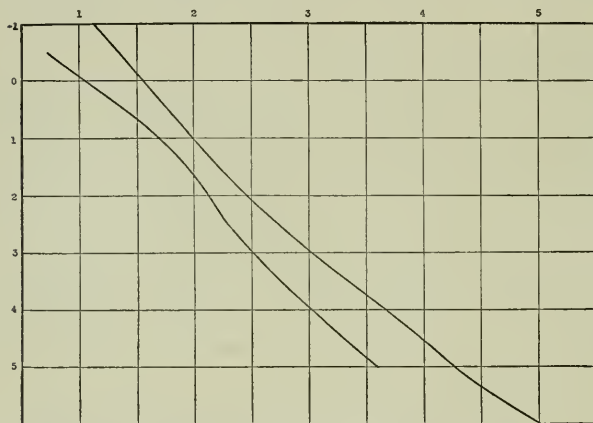
During the past year a large number of observations have been accumulated at Harvard on the luminosities of southern stars of Class M. We have decided, however, to precede the discussion of that material with the present communication, which shows the possibility of using Harvard photographs for the determination of stellar distances, and, by intercomparing the work of different observers, indicates the accuracy of the results to be obtained for stars of favorable spectral types. The measures for this communication were made on the occasion of a recent visit to Cambridge by Dr. Lindblad.

Luminosities and parallaxes are given below for fifty stars with spectra classed as K0 or K2 in the Henry Draper Catalogue. Upon making further

subdivision, the spectra fall within the limits of G7 and K3, inclusive. Most of these stars are in the southern hemisphere, where there has always been a marked deficiency of data relative to stellar distances.

In the determination of the luminosities of these brighter stars, we have used much the same criteria as those employed by the Mount Wilson observers, giving most weight for Class K to the changes with absolute magnitude of the line $\lambda 4215$ of ionized strontium, but also using the "cyanogen" absorption bands, and the lines of hydrogen, calcium, and manganese. For southern stars the plates were made at Arequipa with the 13-inch Boyden telescope and one prism, dispersion $H\beta - H\epsilon = 22$ mm.; for northern stars the plates were made at Cambridge with the 11-inch Draper telescope and one prism, dispersion $H\beta - H\epsilon = 20$ mm.

Curves are given in the figure showing the correlation of absolute magnitude and intensity ratio for the lines $\lambda 4326$ (Fe) and $\lambda 4215$. On Harvard



Relation between ratio of line-intensities (abscissas) and the absolute magnitude (ordinates). Upper curve by Shapley; lower by Lindblad.

plates these lines are not too widely separated for satisfactory comparison; and since $\lambda 4326$ is not greatly different in intensity from the strontium line for the most frequently occurring magnitudes of Class K, it is more suitable as a comparison line than the much fainter iron line $\lambda 4250$, which is used on slit-spectrograms at Mount Wilson.

The luminosities determined from Harvard spectra are based for the present on the Mount Wilson system, which in turn is carefully standardized with parallaxes determined trigonometrically and from parallactic motions. About fifty northern Class K stars, for which absolute magnitudes have been estimated at Mount Wilson,⁴ were used for the initial calibration of the curves connecting luminosity and line intensity. Only a few of the northern stars appear in the table. A detailed comparison of Harvard and Mount Wilson results will be given in a subsequent Circular.

LUMINOSITIES AND DISTANCES OF FIFTY STARS

No.	Name	R. A. 1900	Dec. 1900	Vis. Mag.	H. D. Sp.	Abs. Mag.	Wt.	Res.	π	ΔM	MW Sp.
		<i>h. m.</i>	<i>°</i>						<i>"</i>		
1	ϵ Phoenicis	0 4.3	-46 18	3.39	K0	+1.0	10	4,5	0.033		
2	α Phoenicis	0 21.3	-42 51	2.44	K0	+1.8	12	1,0	0.075		
3	μ Phoenicis	0 36.6	-46 38	4.65	K0	+0.6	7	0,1	0.015		
4	β Phoenicis	1 1.6	-47 15	3.35	K0	+0.7	19	5,5	0.030		
5	ϕ Piscium	1 8.3	+24 3	4.64	K0	+0.7	6	3,3	0.016	3,0,6	G7
6	δ Phoenicis	1 27.0	-49 35	3.96	K0	+1.9	12	10,10	0.039		
7	η^2 Hydri	1 52.4	-68 9	4.72	K0	+2.7	10	3,3	0.039		
8	ι Eridani	2 36.7	-40 17	4.06	K0	+1.8	9	8,9	0.035		
9	β Fornacis	2 44.9	-32 50	4.50	K0	+1.4	6	4,3	0.024		
10	τ^2 Eridani	2 46.5	-21 25	4.81	K0	+0.7	8	4,3	0.015	5,9,2	G8
11	ν Hydri	2 51.1	-75 29	4.70	K2	+1.0	8	2,3	0.018		
12	δ Arietis	3 5.9	+19 21	4.53	K0	+0.3	7	0,1	0.014	4,4,5	K0
13	γ Eridani	3 33.5	-40 36	4.58	K0	+1.0	4	2,1	0.019		
14	h Eridani	3 39.1	-37 38	4.64	K2	+1.2	5	2,3	0.021		
15	β Reticuli	3 42.9	-65 7	3.80	K0	+0.7	9	3,3	0.024		
16	g Eridani	3 45.7	-36 30	4.24	K0	+0.2	11	2,3	0.016		
17	α Horologii	4 10.7	-42 32	3.83	K0	+1.5	13	3,3	0.034		
18	ϵ Reticuli	4 14.7	-59 32	4.42	K2	+2.6	4	4,3	0.043		
19	γ Caeli	5 0.8	-35 37	4.62	K0	+1.0	11	6,6	0.019		
20	$\circ$ Columbae	5 13.9	-35 0	4.91	K0	+2.5	16	10,10	0.033		
21	θ Doradus	5 13.9	-67 18	4.78	K0	+0.4	6	6,5	0.013		
22	ϵ Columbae	5 27.7	-35 33	3.92	K0	+0.2	11	2,2	0.018		
23	δ Leporis	5 47.0	-20 53	3.90	K0	+3.7	12	9,9	0.091	....	G7
24	β Columbae	5 47.4	-35 48	3.22	K0	+0.8	16	3,4	0.033		
25	γ Pictoris	5 48.0	-56 12	4.38	K0	+0.4	7	1,1	0.016		
26	η Columbae	5 56.1	-42 49	4.03	K0	-0.6	9	0,0	0.012		
27	κ Columbae	6 13.0	-35 6	4.51	K0	0.0	8	0,0	0.013		
28	τ Puppis	6 47.5	-50 30	2.83	K0	+0.5	8	2,2	0.034		
29	γ^2 Volantis	7 9.6	-70 20	3.87	K0	+1.5	11	0,0	0.034		
30	ζ Volantis	7 43.0	-72 22	3.89	K0	+1.7	5	6,6	0.036		
31	h^2 Puppis	8 10.5	-40 2	4.43	K0	+0.5	6	1,1	0.016		
32	θ Chamaeleontis	8 23.6	-77 10	4.26	K0	+0.6	8	6,5	0.019		
33	σ Hydrae	8 33.5	+ 3 42	4.54	K0	-0.1	4	3,3	0.012	0,3,3	K2
34	46 Leonis Min.	10 47.7	+34 45	3.92	K0	+1.1	8	3,3	0.027	3,0,6	K1
35	ϵ Corvi	12 5.0	-22 4	3.21	K0	+0.7	17	4,4	0.031	2,6,2	K3
36	π Hydrae	14 0.7	-26 12	3.48	K0	+1.8	12	5,4	0.046		
37	θ Centauri	14 0.8	-35 53	2.26	K0	+1.2	27	0,0	0.061	2,2,2	K1
38	E Hydrae	14 44.5	-27 32	4.63	K2	+2.6	7	4,4	0.039		
39	f Lupi	15 11.7	-29 47	4.43	K0	-0.4	7	4,3	0.011		
40	θ Herculis	17 52.8	+37 16	3.99	K0	-0.6	5	0,1	0.012	3,3,2	G9
41	δ Sagittarii	18 14.6	-29 52	2.84	K0	+0.4	14	1,1	0.033		
42	λ Sagittarii	18 21.8	-25 29	2.94	K0	+3.2	14	3,2	0.113	0,3,2	K0
43	ξ^2 Sagittarii	18 51.8	-21 14	3.61	K0	+0.3	19	2,2	0.022	4,2,6	K0
44	$\circ$ Sagittarii	18 58.7	-21 53	3.90	K0	+1.9	16	3,3	0.040	6,9,3	G8
45	τ Sagittarii	19 0.7	-27 49	3.42	K0	+2.2	9	7,8	0.057		
46	θ Lyrae	19 12.9	+37 57	4.46	K0	-0.4	5	2,3	0.011	6,8,3	K0
47	f Sagittarii	19 40.5	-20 0	5.06	K0	+1.6	5	0,1	0.020	1,1,2	K0
48	b Sagittarii	19 50.8	-27 26	4.62	K2	+0.2	3	3,3	0.013		
49	ϵ Pegasi	21 39.3	+ 9 25	2.54	K0	-0.2	10	3,2	0.028	1,2,3	K0
50	c^2 Aquarii	23 4.1	-21 43	3.80	K0	+0.8	9	2,2	0.025		

The positions, visual magnitudes, and spectral classes in the table are taken from the Henry Draper Catalogue. The absolute magnitudes in the seventh column are means of determinations by the two observers. The weights in the following column depend upon the number of plates, the definition, the density of the spectrum, and its width. The weight for a single plate may range from one to four (rarely five when there are several good exposures on one plate), with an average between two and three. The Harvard spectra of bright stars average more than three millimeters in width, a condition that is of high value in estimating the ratio of intensity for pairs of spectral lines.

The residuals in the ninth column give respectively, Shapley *minus* Mean Abs. Mag., and Lindblad *minus* Mean Abs. Mag. Negative residuals are indicated, as usual, by *Italics*. The mean systematic difference between the observers for the fifty stars is $L - S = +0^m.31$, and varies somewhat with absolute magnitude. The average residual, without correcting for the systematic difference, is $0^m.32$.

The eleventh column of the table contains the differences in absolute magnitude, Harv. - MW, $S - MW$, and $L - MW$, for the stars common to the Harvard and Mount Wilson lists; the spectral classes appearing in the last column are estimated by the Mount Wilson observers. Omitting the very discordant values of ΔM for δ Leporis (viz. 22, 13, 31),⁵ the average and systematic differences between the Mount Wilson and Harvard results for fourteen stars are as follows:—

	H - MW	S - MW	L - MW
Average	$0^m.29$	$0^m.37$	$0^m.34$
Systematic	$- 0 .09$	$- 0 .09$	$- 0 .11$

The differences are satisfactorily small, as the probable error in the Mount Wilson absolute magnitudes is of the order of four tenths of a magnitude for stars of this spectral type.⁶

1. Shapley, *Publ. Am. Ast. Soc.* **3**, 222, 1916.

2. Cf. Seares, *Mt. W. Commun.* 59, 1919;

Shapley, *Publ. A. S. P.* **31**, 278, 1919;

Lindblad, *Upsala Univ. Arsskrift*, 1920.

3. *Mt. W. Contr.* (in press).

4. Adams, Joy, Strömberg, and Burwell, *Mt. W. Contr.* 199, 1920.

5. The annual proper motion, $0''.696$, favors the larger value of the parallax derived at Harvard.

6. *Mt. W. Contr.* 199, p. 15, 1920.

HARVARD COLLEGE OBSERVATORY

CIRCULAR 229

THE LOCAL SYSTEM AND STARS OF CLASS A

BY HARLOW SHAPLEY AND ANNIE J. CANNON

It has been pointed out in various articles published during the last four years that the equatorial plane of an extensive, discoidal, local system of stars appears to be inclined some ten degrees to the galactic plane. The phenomenon is found to be clearly marked for the brighter B stars¹ contained in Harvard Annals 50. Their distribution supports the hypothesis that the local cluster or cloud of stars is distinct from the general field of the Milky Way system. The Herschel-Gould belt of bright stars, the reality of which was challenged by Newcomb, roughly follows the projection of the equatorial plane of the local system of B stars.

The dark nebulae catalogued by Barnard² have also been found to show a preference for this so-called secondary galaxy,³ and Hubble has recently shown that both the extended and the obscuring nebulae appear to cluster along the plane of the local system as well as along the plane of the Galaxy proper.⁴

To what extent the existence of this local system is shown by stars of other classes has not heretofore been closely investigated. If the stars of a given class are not conspicuously concentrated to the equatorial plane of the systems within which they lie, or if they are not wholly restricted to the local system, it is difficult to bring to light the small inclination that is indicated by the B stars.⁵

The stars of Classes N and O, the typical Cepheid variables, and the novae are highly concentrated in the Milky Way, but relatively they are not numerous, and few if any of them belong to the local stellar system.

Of the principal spectral classes, only the early A stars appear to afford a good opportunity of finding a trace of the secondary galaxy. The faint stars of Class A0, according to an unpublished study of their distribution made at

Harvard, show a high concentration to the primary galactic circle, but no trace of the secondary. The present Circular deals with the brighter stars of Classes B8, B9, A0, A2, and A3. The visual magnitude limit has been placed at 6.5.

The distribution of stars with respect to the plane of the Milky Way is conveniently shown by means of galactic coordinates on an Aitoff equal area projection. Figure 1 shows such a chart with the equatorial system of coordinates superposed as dotted lines. In practice, the superposed system of coordinates is traced in pencil, and after the star positions, which are given in right ascension and declination in the Henry Draper Catalogue, are plotted in ink on the equatorial system, the pencilled lines are erased. The result is a chart showing the galactic distribution, made without the trouble of computing or recording individual values of galactic latitude and longitude.

Figure 2 shows the distribution of the 2450 bright A stars.⁶ The tendency toward positive latitudes at the sides of the figure and negative latitudes in the center is apparent upon general inspection of the figure. This tendency is verified quantitatively by the crosses, which designate the smoothed median galactic latitudes for successive intervals of ten degrees in galactic longitude. The smoothed medians were formed by taking overlapping means in groups of three, with double weight for the middle value. The following table contains the median latitude and number of stars for each interval of longitude.

MEDIAN LATITUDES

Longitude	Latitude	Stars	Longitude	Latitude	Stars	Longitude	Latitude	Stars
5	+1	63	125	-1	68	245	-3	61
15	+2	74	135	-2	61	255	-2	78
25	+2	70	145	-5	73	265	0	65
35	+3	74	155	-6	74	275	+3	69
45	+5	71	165	-2	70	285	+5	52
55	+4	73	175	-2	77	295	+7	66
65	+2	78	185	-6	85	305	+7	55
75	+2	56	195	-6	59	315	+3	63
85	+4	68	205	-6	65	325	-2	77
95	+4	82	215	-4	73	335	-4	50
105	+2	58	225	-1	63	345	-2	69
115	0	66	235	-2	67	355	-2	66
						Mean	-0.1	68

In determining the median values, four stars in the Pleiades and twelve in the open cluster in Coma Berenices were omitted. The apparently anomalous negative median latitudes in the vicinity of longitude 340° are partly due to the scarcity of A stars north of the galactic equator in Ophiuchus, and partly to the large ill-defined group of bright stars in and near Corona Austrina. The

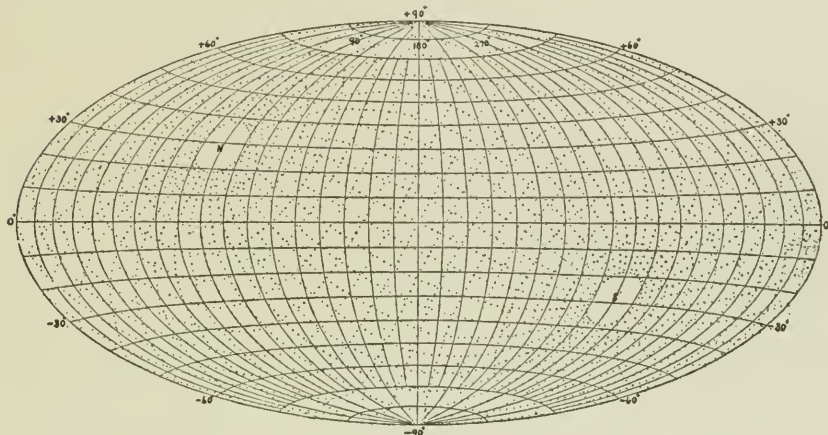


FIG. 1.

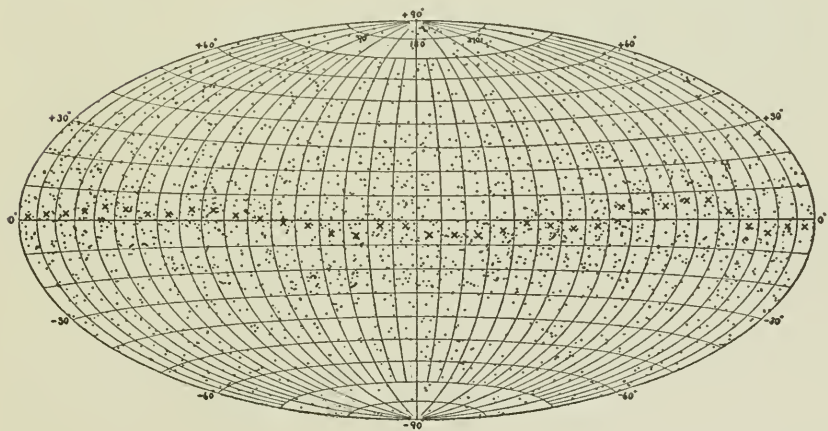


FIG. 2.

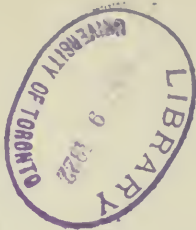
possibility that a moving cluster of bright A stars exists in that region merits investigation from the standpoint of proper motion data.

The mean latitude for the thirty-six values in the table is nearly zero. The inclination is of the order of 5° , which may be considered as the resultant of the true inclination of the local cluster and of the zero inclination for the system of field stars. The uniformity of distribution in longitude is noteworthy; there is little or no evidence of the various groupings found for the B stars, and these A stars are not distinctly more numerous in the direction of the center of either the local system or of the Galaxy proper.

The present investigation appears to confirm the existence of a local cloud of stars. The deviation from the galactic plane is of the same character as that shown by the B stars, but it is less pronounced. From the distributional data now in hand, however, it would be difficult to say whether the local system includes only the bright early B stars and a part of the bright early A stars, or whether all spectral types are represented, but so proportioned and distributed on the surface of the sky that only the more highly concentrated first type stars show the existence of the cluster. For second and third type stars the problem may be further studied through investigations of motions, distances, and density in space.

1. Shapley, *Mt. W. Contr.* 157, 1918. Cf. *Mt. W. Commun.* 54, 1918, and 64, 1919; *Scientia*, March, 1920.
2. Barnard, *Ap. J.* 49, 1, 1919.
3. *Mt. W. Commun.* 62, p. 6, 1919.
4. *Pub. A. S. P.* 33, 304, 1921.
5. Shapley, *A. N. Jubilæumsnummer*, p. 25, 1921.
6. For the manner of grouping into spectral subdivisions, see *H. C.* 226, 1921.

JANUARY 10, 1922.



HARVARD COLLEGE OBSERVATORY

CIRCULAR 230

SPECTRAL CLASS AND MAGNITUDE IN HARVARD STANDARD REGIONS

BY HENRIETTA S. LEAVITT

It is sometimes stated that the stars, on the whole, grow redder with increasing faintness. There are two possible explanations of such a phenomenon, if it exists. Either the stars of the Classes G, K, and M, may increase in number more rapidly than the whiter stars of Classes B, A, and F, or there may be a progressive change in the distribution of light in the continuous spectrum, such as might be caused by a scattering medium in space.

In the latter case, the color indices of stars of the same spectral class would change progressively with magnitude. In the former, there would be no progressive change for a given class of spectrum, but the mean color index for stars of all classes would increase. Of course the two conditions may exist simultaneously. For an investigation of the second hypothesis, it is necessary to employ photographic and photometric or photovisual scales, each of which is calibrated in accordance with Pogson's law, and for each of which the color equation is precisely known, including any variation of scale for different colors. No scale can be considered, as yet, to be so perfectly determined, for faint stars, that it can safely be used for discussing this delicate problem.

On the other hand, to test the first hypothesis, the distribution of stellar spectra according to magnitude is easily investigated to magnitude 8.25 for the whole sky by means of the Henry Draper Catalogue. The discussion of this catalogue is in progress, and some results are given in H. C. 226. Additional material is contained in H.A. 71, No. 4, where in 48 Harvard Standard Regions the spectrum, as classified by Miss Cannon, is given for about 800 stars, together with their photographic magnitudes between 6.5 and 11.5. The material fainter than 10.5 is too scanty to have much weight in the discussion and it may be affected by a type selection, but, even without these

faintest stars, the limit is fully two magnitudes below that of the Henry Draper Catalogue. This circumstance, together with the fact that the magnitudes are photographic and relatively homogeneous, furnishes a partial compensation for the small number of stars. Some results of a count of these stars are given in Table I. They were divided into five groups, according to their photographic magnitudes. All stars between the magnitudes 6.50 and 7.49 are designated in the first column by their central point, 7.0, and so on for fainter stars. Three stars brighter than the magnitude 6.50 were omitted. The letters N, S, P, and M, at the head of the first column in each of the four sections, refer to regions north and south of the Milky Way, partly in it, and mainly in it, according to the arrangement in H.A. 64, 94, Table II. Each section comprises 12 H. S. Regions. The second to the eighth columns give the number of stars of the different spectral classes and of all combined.

The groups B, A, F, G, K, and M, consist respectively of stars of Classes B0 to B8, B9 to A3, A5 to F2, F5 to G2, G5 to K2, and K5 to M. It is found, by counting, that the actual mean values of the several groups are nearly B5, A1, A9, F9, G9, and K6, and the corresponding color indices according to H.A. 80, 151, Table IV, are -0.12 , $+0.03$, $+0.25$, $+0.53$, $+0.96$, and $+1.21$, respectively. The ninth column gives the mean computed value of the color index for each magnitude, based on the numbers of stars in the

TABLE I
DISTRIBUTION OF SPECTRAL CLASSES

Magn.	Reg.	B	A	F	G	K	M	All	C. I.	Sp.	Reg.	B	A	F	G	K	M	All	C. I.	Sp.
7.0	N	1	6	9	7	9	1	33	0.48	F7	P	.	14	2	7	10	.	33	0.43	F5
8.0		1	5	10	20	17	.	53	0.56	G0		.	17	3	16	14	3	53	0.50	F8
9.0		.	1	12	13	16	6	48	0.68	G3		.	17	10	11	17	3	58	0.50	F8
10.0		.	.	4	17	17	2	40	0.72	G4		.	5	3	13	22	4	47	0.72	G4
11.0		.	.	.	6	19	2	27	0.88	G7		.	1	.	.	5	3	9	0.94	G9
All		2	12	35	63	78	11	201	0.65	G2		.	54	18	47	68	13	200	0.56	G0
7.0	S	.	10	6	4	4	1	25	0.36	F3	M	6	11	4	4	3	.	28	0.20	A7
8.0		.	10	14	16	25	1	66	0.57	G0		10	31	2	8	10	2	63	0.26	A9
9.0		.	9	8	21	22	2	62	0.60	G1		2	32	3	5	13	3	58	0.35	F2
10.0		.	2	2	10	29	1	44	0.79	G5		1	20	.	8	12	3	44	0.45	F6
11.0		.	.	.	1	4	.	5	0.87	G7		.	2	.	2	2	.	6	0.51	F8
All		.	31	30	52	84	5	202	0.61	G1		19	96	9	27	40	8	199	0.33	F2

different classes. The corresponding class of spectrum, as given in the tenth column, was found by interpolation in H.A. 80, 151, Table IV.

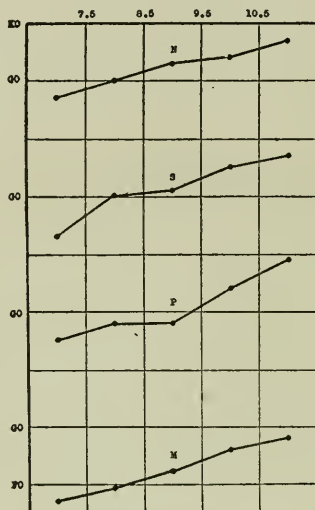
In order to make the quantities in Table I more directly comparable with one another, all have been reduced to percentages of the whole number in each magnitude group. Each number in Table I was divided by the number in the column headed "All," and the resulting quantities, omitting the decimal points, are given in the four sections of Table II, in nearly the same form as Table I. The sum of all the quantities on any line, within a section, is always nearly 100.

TABLE II
PROPORTIONS

Magn.	N						S						P						M					
	B	A	F	G	K	M	B	A	F	G	K	M	B	A	F	G	K	M	B	A	F	G	K	M
7.0	03	18	27	21	27	03	.	40	24	16	16	04	.	42	06	21	30	.	21	39	14	14	11	.
8.0	02	09	19	38	32	.	.	15	21	24	38	02	.	32	06	30	26	06	16	49	03	13	16	03
9.0	.	02	25	27	33	13	.	15	13	34	35	03	.	29	17	19	29	05	03	55	05	09	22	05
10.0	.	.	10	42	42	05	.	05	05	23	66	02	.	11	06	28	47	09	02	45	.	18	27	07
11.0	.	.	.	22	70	08	.	.	.	20	80	.	.	11	.	.	56	33	.	33	.	33	33	.
All	01	06	18	31	39	05	.	15	15	26	42	02	.	27	09	24	34	06	10	48	04	14	20	04

The means of the results in the last line of Table II give, for the combined regions, the proportions 03, 24, 12, 24, 34, and 04, for Classes B, A, F, G, K, and M, respectively. The proportion of stars of Class B, in the regions discussed, falls off rapidly, becoming very small near the eighth magnitude outside, and near the tenth magnitude inside the Milky Way. The proportion for stars of Class A diminishes rapidly in Sections N and S, becoming very small near the tenth magnitude; but the falling off is more gradual in Section P, and is slow, and perhaps doubtful, in Section M. The stars of Class F show some curious anomalies which may be due, in part, to their comparatively small number. In Sections N and S, they are more numerous than stars of Class A, but the proportion is smaller in Section P, and becomes insignificant in Section M. Their relative number appears to diminish with increasing faintness, but the effect is not striking if the magnitude group 7.0 is omitted. Stars of Classes G, K, and M show little change relative to one another, with respect either to galactic position or to magnitude.

The results obtained above are shown in the accompanying figure. Abscissas represent magnitudes, taken from the first column of Table I. Ordinates represent the approximate mean class of spectrum, taken from the last columns of the four sections of the same table.



Variation of average spectral class with magnitude

The progressive change in the average class of spectrum will make the stars included in H.A. 71, taken all together, appear redder with increasing faintness, from the seventh to the tenth or eleventh magnitude. We have no data, at present, to indicate whether stars fainter than the eleventh magnitude continue to have spectra of increasingly redder classes.

OCTOBER, 1921.

HARVARD COLLEGE OBSERVATORY

CIRCULAR 231

STARS HAVING PECULIAR SPECTRA. EIGHT NEW
VARIABLE STARS

BY ANNIE J. CANNON

THE peculiar spectra given in the following table were found during observations for the Henry Draper Catalogue or by examination of later spectroscopic photographs. They comprise six new double and eight new variable stars. The variability of $+56^{\circ} 673$ was found by Miss Walker, that of $-6^{\circ} 4638$ and of $-7^{\circ} 5271$, by Miss Woods, and that of the remaining five, by the writer. The variation of each star has been confirmed by a second observer.

Successive columns of the table give the Durchmusterung number, the right ascension for 1900, the declination for 1900, the Durchmusterung or photometric magnitude, the class of spectrum, and brief remarks. Additional facts are stated in the Remarks following the table.

The letters H.V. in the table indicate the current number in the series of variable stars discovered at this Observatory or on photographs made here. The first variable discovered at Harvard was T Orionis, found by Professor George P. Bond in 1863. The second and third, U Puppis and R Ursae Minoris, were found by Professor E. C. Pickering in 1881. The number of new variables announced each year is as follows:

1863	1	1892	7	1897	4	1902	4	1907	169	1913	25	1919	86
1881	2	1893	4	1898	36	1903	11	1908	127	1914	7	1920	11
1889	1	1894	10	1899	1	1904	427	1909	22	1916	35	1921	67
1890	7	1895	29	1900	1	1905	10	1910	98	1917	22	1922	10
1891	5	1896	22	1901	593	1906	1715	1911	40	1918	1	Total	3610

Since 1889, when H. V. 4 = S Centauri was found, new variable stars have been announced every year except 1912 and 1915. The first star for which variability was inferred from the bright lines in the photographic spectrum was R Caeli = H. V. 8. Professor Bailey's discoveries of variable stars in

globular clusters were announced mainly in 1901. Most of the variables found in the Orion Nebula, the Milky Way Clouds, and the Magellanic Clouds were announced in 1904 and 1906 by Miss Leavitt, who discovered more than one-half of all known variable stars.

STARS HAVING PECULIAR SPECTRA. EIGHT NEW VARIABLE STARS

DM.	R.A. 1900	Dec. 1900	Magn.	Sp.	Remarks
+56° 673	<i>h. m. s.</i> 2 31.2	+56 37	8.3	..	Variable. H.V. 3602. —Camelopardalis.
+56° 779	3 1.0	+56 16	8.0	K0	Composite spectrum. H.D. 19278.
	3 1.0	+56 16		A3	
+40° 1043	4 39.5	+40 43	8.5	K0	Composite spectrum.
	4 39.5	+40 43		A	
....	5 9.6	-64 26	..	Md	Variable. U Doradus. H.V. 2934.
-18° 3528	12 56.6	-19 15	7.8	A3	Variable. H.V. 3603. — Virginis. H.D. 113158.
....	13 58.0	-66 32	..	Pec.	Variable. H.V. 3604. — Circini.
-58° 5962	15 21.8	-58 14	9.6	Oe	H.D. 137603.
- 6° 4638	17 38.6	- 6 14	8.8	Bp	Variable. H.V. 3605. — Ophiuchi. H.D. 161114.
....	17 58.8	-36 39	..	Pd	Gaseous nebula.
-22° 4561	18 0.7	-22 28	8.5	K0	Composite spectrum. H.D. 165407.
	18 0.7	-22 28		A	
-47° 12093	18 3.2	-47 10	9.4	G5	Composite spectrum. H.D. 165934,5.
	18 3.2	-47 10		A3	
....	18 8.1	+14 54	..	R0	
....	18 39.0	+22 54	..	Pec.	Variable. H.V. 3606. — Herculis.
+12° 3818	19 3.6	+12 6	7.50	G5	Composite spectrum. H.D. 178452,3.
	19 3.6	+12 6		A2	
+20° 4390	19 58.0	+20 48	9.0	Nb	
- 7° 5271	20 16.8	- 7 40	9.4	A2	Variable. H.V. 3607. — Aquilae.
+67° 1443	22 26.8	+67 42	7.8	G5	Composite spectrum.
	22 26.8	+67 42		A0	
....	23 53.6	-40 0	..	..	Variable. H.V. 3608. — Phoenicis.
-25° 16760	23 57.7	-25 30	9.1	A0	Variable. H.V. 3609. — Sculptoris.

REMARKS

- 2 31.2. No. 53 in "The Red Stars," Cunningham Memoirs, No. 5. The spectrum is not visible on 8 photographs taken here. The photographic range of variation is from magnitude 9.6 to 10.4.
- 3 1.0. A photograph taken with the 16-inch Metcalf Telescope shows the composite nature of the spectrum.
- 12 56.6. A variable star of the Algol type. The photographic range is from magnitude 8.2 to 8.9. The variation was confirmed by Miss Carpenter and Miss

- Wells. The variable was at or near minimum on April 18 and July 15, 1915, July 18, 20, and 26, 1916, and April 13, 1918.
- 13 58.0. The position for 1875 is R.A. 13^h 56^m 4^s, Dec. -66° 24'.6. The spectrum is faint and resembles that of R Andromedae at minimum. The photographic range is from magnitude 12.2 to 13.4.
- 17 38.6. This variable has been observed by Miss Woods on 264 photographs taken between 1898 and 1921. The photographic range is from magnitude 9.6 to

- 10.7. Long durations of both maximum and minimum phases occur. The star was at or near minimum light during the whole year 1921.
- 17 55.8. The position for 1855 is R. A. $17^h 54^m 4^s.6$, Dec. $-36^\circ 38'.8$.
- 18 8.1. The position for 1855 is R. A. $18^h 6^m 4^s.2$, Dec. $+14^\circ 53'.3$.
- 18 39.0. The position for 1855 is R. A. $18^h 37^m 56^s.7$, Dec. $+22^\circ 52'.5$. On a photograph taken June 15, 1909, a faint spectrum is visible, having the line $H\gamma$ 10 times as bright as $H\delta$. The continuous spectrum is brightest between $H\beta$ and $H\gamma$, and it may resemble that of R Andromedae. The period is long. The range of variation on 10 photographs which were observed is from magnitude 10.4 to 15.
- 20 16.8. This star was faint on 6 out of 85 photographs which were examined by Miss Woods. Probably of the Algol type. The photographic range is from magnitude 9.8 to 11.1.
- 23 53.6. The photographic range is from magnitude 10 to < 12 . The period appears to be long.
- 23 57.7. The photographic range of variation is from magnitude 9.8 to 10.7. Probably of the Algol type.

FEBRUARY 13, 1922.



HARVARD COLLEGE OBSERVATORY

CIRCULAR 232

THE DISTANCES OF 87 BRIGHT STARS OF CLASS K

BY HARLOW SHAPLEY AND MARTHA B. SHAPLEY

THE first report on the determination at Harvard by spectro-photometric methods of the distances of stars of spectral Class K (G7 to K3) was given in Circular 228. The material brought together in the present circular permits the comparison of the absolute magnitudes derived at Harvard from objective prism spectra with those obtained at Mount Wilson from photographs made with slit spectroscopes.

The Harvard absolute magnitudes, as before, are based directly on the system established at Mount Wilson (Mt. W. Contr. 199, 1920), but new curves have been deduced for the relation of luminosity to ratio of line intensities. Each observer has derived separate curves for the spectral classes G7 to K0 and K1 to K3.

Table I contains in the first column the numbers of the stars in the Harvard series of measurements of distance, continuing the numbering from H. C. 228. The sixth, seventh, and eighth columns contain the Harvard and Mount Wilson classifications and the difference between them in units of spectral type (tenths of a spectral class). The Harvard spectra are the means of estimates by the two observers, and differ, mainly in being more closely subdivided, from the classes appearing in the Henry Draper Catalogue.

The absolute magnitudes in the ninth column are not of high weight for the dwarf stars, because the curves are not yet well established for the fainter magnitudes. The system of relative weights, tenth column, is based on the number and quality of plates, and differs quantitatively from the system used in Table II below, and in H. C. 228. The residuals in absolute magnitude in the eleventh column, expressed in tenths, are: H.S. - Mean, and M.B.S. - Mean. The average residual is two tenths of a magnitude. The systematic difference between the results for the two observers is H.S. - M.B.S. = + 0^m.06.

TABLE I
LUMINOSITIES AND DISTANCES OF EIGHTY-SEVEN STARS

No.	Name	R. A. 1900	Dec. 1900	Vis. Mag.	Sp.	MW Sp.	Δ Sp.	Abs. Mag.	Rel. Wt.	Res.	π	ΔM
		<i>h. m.</i>	<i>° ' "</i>								<i>"</i>	
51	54 Piscium	0 34.2	+20 43	6.1	G8	K1	3	6.8	...	...	0.138	6
52	43 H. Cephei	0 55.0	+85 43	4.5	K4	K3	1	0.2	2	3,3	0.014	3
53	ψ Cassiopeiae	1 18.9	+67 36	5.0	K1	K1	0	0.5	2	0,0	0.013	3
54	τ Ceti	1 39.4	-16 28	3.6	G8	G7	1	6.1	2	2,2	0.316	0
55	ξ Piscium	1 48.4	+2 42	4.8	G9	G7	2	0.9	2	1,0	0.017	2
56	γ^1 Andromedae	1 57.8	+41 51	2.3	K1	K2	1	0.8	4	1,1	0.050	9
56	α Arietis	2 1.5	+22 59	2.2	K1	K2	1	1.3	4	0,1	0.066	6
58	39 Arietis	2 42.0	+28 50	4.6	K0	K1	1	0.6	2	0,0	0.016	6
59	κ Persei	3 2.7	+44 29	4.0	G9	K0	1	0.4	2	3,4	0.019	5
60	ω Persei	3 4.8	+39 14	4.8	G9	K1	2	0.7	3	2,2	0.015	2
61	σ Tauri	3 19.4	+ 8 41	3.8	G9	G7	2	0.3	3	4,6	0.020	2
62	ϵ Eridani	3 28.2	- 9 48	3.8	K1	K1	0	6.0	2	1,0	0.275	0
63	δ Eridani	3 38.5	-10 6	3.7	K0	G9	1	2.4	2	6,5	0.055	10
64	σ^2 Eridani	4 10.7	- 7 49	4.5	K0	K1	1	6.9	1	1,1	0.302	7
65	γ Tauri	4 14.1	+15 23	3.9	G8	G7	1	0.2	2	2,1	0.018	5
66	δ Tauri	4 17.2	+17 18	3.9	G8	G9	1	0.7	3	2,2	0.023	3
67	θ^1 Tauri	4 22.9	+15 44	4.0	G9	G9	0	0.2	3	1,1	0.017	12
68	ι Aurigae	4 50.5	+33 0	2.9	K2	K3	1	0.8	4	1,2	0.038	8
69	π^6 Orionis	4 53.4	+ 1 34	4.7	K1	K2	1	0.9	2	0,1	0.017	7
70	ν Aurigae	5 44.6	+39 7	4.2	K0	K0	0	0.1	2	0,1	0.015	1
71	κ Aurigae	6 9.0	+29 32	4.4	K0	G8	2	1.4	2	2,1	0.025	9
72	18 Monocerotis	6 42.6	+ 2 31	4.7	G9	K0	1	0.4	2	1,1	0.014	2
73	ι Geminorum	7 19.5	+28 0	3.9	G8	G8	0	1.3	2	6,6	0.030	8
74	κ Geminorum	7 38.4	+24 38	3.7	K0	G7	3	0.0	2	1,0	0.018	9
75	β Geminorum	7 39.2	+28 16	1.2	K1	G9	2	1.4	3	1,1	0.110	3
76	δ Cancri	8 39.0	+18 31	4.2	K1	G9	2	0.0	2	1,0	0.014	3
77	κ Leonis	9 18.8	+26 37	4.6	K1	K2	1	1.3	2	2,1	0.022	0
78	11 Leonis Minoris	9 29.7	+36 16	5.5	G8	K1	3	5.0	2	1,2	0.080	4
79	μ Leonis	9 47.1	+26 29	4.1	K3	K3	0	0.5	2	0,0	0.019	1
80	λ Hydrae	10 5.7	-11 52	3.8	G9	K0	1	-0.1	2	1,1	0.017	6
81	ν Hydrae	10 44.7	-15 40	3.3	K0	K1	1	0.7	2	0,2	0.030	3
82	α Ursae Majoris	10 57.6	+62 17	2.0	G9	G8	1	0.3	3	0,1	0.046	1
83	ψ Ursae Majoris	11 4.0	+45 2	3.2	K0	K0	0	1.3	2	1,0	0.042	0
84	δ Crateris	11 14.3	-14 14	3.8	G9	G9	0	0.9	3	3,4	0.026	2
85	τ Leonis	11 22.8	+ 3 24	5.2	G8	G7	1	1.1	2	4,2	0.015	10
86	χ Ursae Majoris	11 40.8	+48 20	3.8	K1	K0	1	1.8	2	2,3	0.040	5
87	15 Comae Beren.	12 22.0	+28 49	4.6	K0	K2	2	0.5	2	1,0	0.015	2
88	γ Hydrae	13 13.5	-22 39	3.3	G9	G7	2	0.6	2	1,1	0.029	3
89	κ Virginis	14 7.6	- 9 49	4.3	K2	K2	0	3.3	3	2,2	0.063	23
90	4 Ursae Minoris	14 9.2	+78 1	5.0	K3	K3	0	2.0	2	2,2	0.025	13
91	α Bootis	14 11.1	+19 42	0.2	K2	K0	2	1.8	4	4,7	0.209	6
92	ψ Bootis	15 0.2	+27 20	4.7	K2	K2	0	0.5	2	1,1	0.014	4

No.	Name	R. A. 1900	Dec. 1900	Vis. Mag.	Sp.	MW Sp.	Δ Sp.	Abs. Mag.	Rel. Wt.	Res.	τ	ΔM
		^{h.} ^{m.}	[°] [']								["]	
93	α Serpentis	15 39.3	+ 6 44	2.8	K2	K2	0	1.0	2	3.4	0.044	12
94	κ Coronae Borealis	15 47.5	+35 58	4.8	G9	K1	2	1.7	2	0.1	0.024	1
95	ξ Coronae Borealis	16 18.2	+31 7	4.7	G9	G9	0	0.4	3	1.0	0.014	3
96	g Draconis	16 40.2	+64 47	5.0	K0	K1	1	1.9	2	4.4	0.024	5
97	A Ophiuchi	17 9.2	-26 27	n	G8	K1	3	6.4	...	...	0.166	1
98	41 Ophiuchi	17 11.5	- 0 20	4.8	K0	K2	2	0.6	2	1.0	0.014	6
99	λ Herculis	17 26.7	+26 11	4.5	K2	K2	0	1.4	2	1.2	0.024	10
100	f Draconis	17 32.4	+68 12	5.2	G9	G9	0	1.2	3	2.3	0.016	1
101	β Ophiuchi	17 38.5	+ 4 37	2.9	K3	K2	1	0.6	2	2.1	0.035	0
102	θ Herculis	17 52.8	+37 16	4.0	K0	G9	1	-0.1	3	0.1	0.015	2
103	ν Ophiuchi	17 53.5	- 9 46	3.5	G7	G7	0	0.4	2	2.2	0.024	6
104	ξ Herculis	17 53.9	+29 16	3.8	G8	G7	1	0.9	2	3.2	0.026	0
105	93 Herculis	17 55.6	+16 45	4.7	K0	K2	2	0.5	2	3.2	0.014	8
106	70 Ophiuchi Br.	18 0.4	+ 2 31	4.3	K0	K0	0	5.8	2	0.1	0.200	0
107	η Serpentis	18 16.1	- 2 55	3.4	G8	G8	0	1.9	2	2.2	0.050	6
108	ζ Scuti	18 18.2	- 8 59	4.8	G9	G8	1	1.3	2	8.8	0.020	9
109	109 Herculis	18 19.4	+21 43	3.9	K1	K1	0	2.6	2	9.8	0.055	11
110	42 Draconis	18 25.7	+65 30	5.0	K1	K1	0	1.5	2	2.2	0.020	2
111	α Draconis	18 49.7	+59 16	4.8	K0	G8	2	0.5	3	2.1	0.014	10
112	ϵ Aquilae	18 55.1	+14 56	4.2	K0	K1	1	0.3	2	1.0	0.017	7
113	i Aquilae	18 56.3	- 5 53	4.2	K1	K1	0	1.0	2	1.0	0.023	10
114	κ Cygni	19 14.8	+53 11	4.0	K0	G7	3	0.3	2	4.3	0.018	8
115	μ Aquilae	19 29.2	+ 7 10	4.6	K1	K3	2	1.3	2	0.0	0.022	6
116	σ Draconis	19 32.6	+69 29	4.8	K0	G9	1	5.7	2	3.2	0.152	1
117	54 Sagittarii	19 35.0	-16 31	5.4	K1	K1	0	1.0	3	1.1	0.013	7
118	β Sagittae	19 36.6	+17 15	4.4	G9	G8	1	0.3	3	0.1	0.015	3
119	γ Aquilae	19 41.5	+10 22	2.8	K4	K3	1	0.5	3	2.2	0.035	2
120	ξ Aquilae	19 49.4	+ 8 12	4.9	K0	G9	1	1.0	2	2.3	0.017	2
121	η Cygni	19 52.6	+34 49	4.0	K1	K0	1	1.7	2	4.6	0.035	1
122	σ Capricorni	20 13.6	-19 26	5.5	K2	K2	0	0.4	2	2.2	0.010	9
123	52 Cygni	20 41.5	+30 21	4.3	K0	G8	2	0.8	4	3.3	0.020	4
124	ϵ Cygni	20 42.2	+33 36	2.6	K0	G7	3	1.4	3	2.3	0.058	6
125	1 Pegasi	21 17.5	+19 23	4.2	K1	K0	1	1.2	3	2.1	0.025	2
126	72 Cygni	21 30.7	+38 5	5.0	K0	G9	1	0.1	2	1.2	0.010	5
127	ζ Capricorni	21 39.7	- 9 33	5.3	G8	G7	1	-0.3	2	1.1	0.008	2
128	11 Cephei	21 40.5	+70 51	4.8	K0	K1	1	0.8	2	3.3	0.016	2
129	1 Lacertae	22 11.6	+37 15	4.2	K2	K3	1	0.0	2	2.3	0.014	4
130	3 Lacertae	22 19.6	+51 44	4.6	K0	G8	2	1.5	2	1.2	0.024	6
131	11 Lacertae	22 36.1	+43 45	4.6	K2	K2	0	1.0	3	1.2	0.019	3
132	ι Cephei	22 46.1	+65 40	3.7	K0	K0	0	1.5	2	3.2	0.036	4
133	34 H. Cephei	22 47.9	+82 37	5.0	K2	K2	0	1.4	2	3.2	0.019	2
134	3 Andromedae	22 59.7	+49 30	4.9	K0	G9	1	1.0	2	2.3	0.017	3
135	ψ^1 Aquarii	23 10.7	- 9 38	4.5	K0	K0	0	0.8	2	1.2	0.018	6
136	α Cephei	23 14.5	+67 34	5.0	G7	G7	0	0.4	2	3.4	0.013	3
137	78 Pegasi	23 39.0	+28 48	5.0	G8	G7	1	1.1	2	1.2	0.017	0

The last column contains the difference in absolute magnitude, Harvard minus Mount Wilson. A few of the stars, particularly those with the largest differences in this column, merit special comment:

67. θ^1 Tauri. The mean of the Harvard and Mount Wilson magnitudes agrees with that derived from proper motion.

89. κ Virginis. The annual proper motion is $0''.130$.

93. α Serpentis. The absolute magnitude derived from available trigonometric parallaxes is 1.5.

97. A Ophiuchi. The components of this binary star are not separated on the Harvard plates. The visual apparent magnitude is 5.3.

109. 109 Herculis. The annual proper motion is $0''.324$, favoring the larger value of the parallax derived at Harvard, but the trigonometric parallax is only one half the smaller value derived at Mount Wilson.

The absolute magnitudes of seven additional stars, which were included by Shapley and Lindblad in H. C. 228, have been independently determined in the course of the present study from plates not previously used. The results appear in Table II, the original numbering being retained. The weighted means of the two Harvard measurements differ very little from the values previously determined. The agreement with Mount Wilson in type and magnitude is also satisfactory, except for δ Leporis which has been commented on before.

TABLE II
REMEASUREMENT OF DISTANCES

No.	Name	R. A. 1900		Dec. 1900	Vis. Mag.	Sp.	Abs. Mag.	Wt.	H. C. 228	Wt.	Mean M	π	MW Sp.	MW M
		<i>h.</i>	<i>m.</i>	<i>°</i>										
5	ϕ Piscium	1	8.3	+24 3	4.6	G8	0.9	5	0.7	6	0.8	0.017	G7	0.4
12	δ Arietis	3	5.9	+19 21	4.5	G9	0.6	6	0.3	7	0.4	0.015	K0	0.7
23	δ Leporis	5	47.0	-20 53	3.9	G9	3.9	8	3.7	12	3.8	0.096	G7	1.5
33	σ Hydrae	8	33.5	+ 3 42	4.5	K1	0.4	4	-0.1	4	0.2	0.014	K2	-0.1
34	46 Leonis Minoris	10	47.7	+34 45	3.9	K1	1.6	2	1.1	8	1.2	0.029	K1	1.4
35	ϵ Corvi	12	5.0	-22 4	3.2	K0	0.0	3	0.7	17	0.6	0.030	K3	0.5
46	θ Lyrae	19	12.9	+37 57	4.5	G8	0.1	5	-0.4	5	-0.2	0.012	K0	0.2

The average difference in spectral classification between Harvard and Mount Wilson is one spectrum unit for the 94 stars in Tables I and II. The largest difference is three units, and the systematic difference is negligible.

Excluding the abnormal residuals in absolute magnitude for κ Virginis and δ Leporis, there are one hundred values of ΔM available from Tables I and II and from H. C. 228. The average difference between Harvard and Mount Wilson is four tenths of a magnitude. The systematic difference is five hundredths of a magnitude, the Harvard observers making the stars relatively fainter.



HARVARD COLLEGE OBSERVATORY

CIRCULAR 233

THE ORBIT OF THE SPECTROSCOPIC BINARY ζ CENTAURI

BY ANTONIA C. MAURY

The binary nature of ζ Centauri was discovered by Mrs. Fleming in 1898 and its period was found by Professor Bailey in the following year. The relative orbit has now been determined from photographs taken at the Harvard Station at Arequipa, Peru, with the 13-inch Boyden telescope and objective prisms, during the years 1892 to 1919.

The spectrum of the brighter component is B2, and that of the fainter, B2 or B3. The ratio of their intensities is about six tenths, but is subject to slight variation.

Measures of velocity were made on the thirty-five plates showing the lines distinctly double; in addition, the velocity was estimated on the entire series of photographs. The estimates were made in hundredths of the maximum separation, being based on the width where the lines were single, and later were reduced to kilometers a second by means of a curve correlating estimates and measures.

The velocity from estimates is given in Table I. The number in the second column gives the quality of the plate on a scale in which 5 denotes the best. The accompanying letter further designates the character of the plate as follows: the letters A, B and C signify that the lines are double, A, with excellent definition, B, with good and C, with poor; the letter D indicates that the lines are narrow and single; E denotes a poor plate and *E*, one having defects likely to cause large error in the estimate. The letter F denotes lines wide and hazy, without clear separation. The number of revolutions since the adopted epoch is given in the third column and, in the fourth, the phase computed from the zero point of recession of the bright star. The plates were all taken with two prisms except the first two and the last six, for which only one prism was used.

The absolute measures were made with the micrometer attachment known as the sliding wire and described in H. A. 84, No. 6, p. 173. The lines included were, in order of frequency, 4388, 4472, 4026, H γ and H δ , and occasionally H ϵ , 4009, 4120 and 4922. Double weight was given to the best lines in taking the means. The velocity from measures is given in Table II.

TABLE I
VELOCITY FROM ESTIMATES

J. D.	Des.	N	Phase	Velocity	O-C	J. D.	Des.	N	Phase	Velocity	O-C
2400000 +			Days	Km	Km	2400000 +			Days	Km	Km
12267.599	4C	- 181	0.824	+228	-134	14829.550	5D	+ 138	3.119	0	- 50
13009.570	5D	- 89	4.587	0	+ 86	14830.578	5D	"	4.147	0	+ 49
13722.615	5D	0	3.496	0	- 12	14832.546	5B	"	6.115	-210	0
13946.870	5D	+ 28	3.079	+107	+ 53	14832.590	5C	"	6.159	-202	+ 8
14438.708	4F	+ 89	5.453	-152	+ 7	14833.537	5B	"	7.106	-268	- 8
14461.604	5D	+ 92	4.277	- 33	+ 27	14833.609	5A	"	7.178	-268	- 8
14482.533	4B	+ 95	1.134	+312	- 12	14833.678	5C	"	7.247	-219	+ 38
14793.493	4C	+ 133	7.182	-284	- 24	14834.592	2E	+ 139	0.137	0	-110
14795.487	5A	+ 134	1.152	+325	+ 4	14834.702	2E	"	0.247	+194	- 6
14797.497	5D	"	3.162	+ 33	- 14	14835.527	4B	"	1.072	+325	- 9
14798.490	5D	"	4.155	0	+ 50	14835.637	5A	"	1.182	+325	+ 7
14799.473	5F	"	5.138	-107	+ 25	14838.581	5D	"	4.126	0	+ 46
14800.496	5C	"	6.161	-190	+ 21	14846.516	5D	+ 140	4.037	0	+ 38
14801.496	5B	"	7.161	-268	- 8	14858.519	5D	+ 141	8.016	0	+ 1
14802.511	5F	+ 135	0.152	+107	- 13	14860.506	5F	+ 142	1.979	+169	- 21
14804.520	4F	"	2.161	+188	+ 23	14862.511	5D	"	3.984	0	+ 31
14805.473	4F	"	3.114	+107	+ 56	14872.519	5F	+ 143	5.968	-190	+ 9
14805.601	5D	"	3.242	+107	+ 68	14885.515	4F	+ 145	2.916	+148	+ 75
14805.655	4D	"	3.296	+120	+ 89	14888.519	3F	"	5.920	-169	+ 24
14805.712	5D	"	3.353	0	- 26	15913.520	4D	+ 273	3.849	0	+ 20
14806.488	5D	"	4.129	0	+ 46	15915.504	5F	"	5.833	-152	+ 35
14807.475	5D	"	5.116	-107	+ 23	15924.628	5B	+ 274	6.933	-245	+ 11
14808.505	5F	"	6.146	-194	+ 16	15925.603	5D	"	7.908	0	+ 80
14809.612	4C	"	7.253	-245	+ 12	15926.576	5A	+ 275	0.857	+337	- 23
14809.679	5B	"	7.320	-245	+ 8	15927.566	5F	"	1.847	+182	- 28
14810.525	5F	+ 136	0.142	+107	- 4	15938.514	3D	+ 276	4.771	- 33	+ 68
14811.496	5A	"	1.113	+357	+ 29	15938.559	4D	"	4.816	- 33	+ 71
14812.474	4F	"	2.091	+152	- 22	15939.513	4F	"	5.770	-152	+ 30
14812.650	4F	"	2.267	+152	+ 2	15939.558	5F	"	5.815	-152	+ 35
14813.496	5D	"	3.113	+ 67	+ 16	15940.515	4F	"	6.772	-182	+ 68
14814.482	5D	"	4.099	- 67	- 24	15940.604	4C	"	6.861	-219	+ 34
14815.485	5D	"	5.102	-107	+ 23	15941.526	5D	"	7.783	0	+150
14816.488	4C	"	6.105	-210	- 1	15941.603	5D	"	7.860	- 67	+ 43
14817.488	4C	"	7.105	-245	+ 15	16153.874	4D	+ 303	3.483	0	- 13
14817.584	4B	"	7.201	-268	- 9	16166.773	5B	+ 305	0.334	+284	+ 28
14818.485	4D	+ 137	0.078	+ 33	- 32	16305.528	4D	+ 322	2.681	+ 67	- 33
14818.562	4D	"	0.155	+120	- 5	16306.547	4D	"	3.700	- 33	- 25
14819.569	5A	"	1.162	+325	+ 5	16307.504	4D	"	4.657	- 92	0
14820.495	5C	"	2.088	+169	- 5	16309.523	4F	"	6.676	-182	+ 64
14821.491	4D	"	3.084	+ 67	+ 13	16335.514	4C	+ 326	0.571	+325	- 24
14822.588	5D	"	4.181	- 67	- 17	17066.524	4F	+ 417	1.397	+228	- 53
14826.511	5D	+ 138	0.080	+107	+ 41	17067.524	3F	"	2.397	+135	+ 2
14826.619	4D	"	0.188	+107	- 42	17068.497	3D	"	3.370	+ 33	+ 8
14827.480	5A	"	1.049	+357	+ 18	17069.528	5D	"	4.401	0	+ 70
14827.595	5A	"	1.164	+325	+ 5	17070.506	4F	"	5.379	-135	+ 17
14827.649	5A	"	1.218	+325	+ 15	17072.499	4F	"	7.372	-182	+ 67
14828.545	5F	"	2.114	+160	- 10	17073.514	4F	+ 418	0.363	+284	+ 13
14828.622	5F	"	2.191	+160	0	17075.524	3F	"	2.373	+135	- 3

J. D.	Des.	N	Phase	Velocity	O-C	J. D.	Des.	N	Phase	Velocity	O-C
2400000 +			Days	Km	Km	2400000 +			Days	Km	Km
17076.517	5D	+ 418	3.366	0	- 24	18480.565	3E	+ 593	3.214	+ 33	- 7
17077.519	3D	"	4.368	- 33	+ 34	18506.521	4F	+ 596	5.098	-124	+ 6
17430.531	4D	+ 462	4.324	-107	- 45	18507.512	4F	"	6.089	-182	+ 25
17432.540	4F	+ 462	6.333	-215	+ 9	19250.539	2E	+ 689	2.884	+152	+ 74
18467.605	3F	+ 591	6.302	-182	+ 39	21011.644	3F	+ 908	6.733	-182	+ 67
18474.618	3E	+ 592	5.291	-147	- 1	21034.571	3F	+ 911	5.588	-107	+ 63
18475.591	3E	"	6.264	-182	+ 38	21048.616	4D	+ 913	3.585	+ 67	+ 63
18476.594	2E	"	7.267	-190	+ 66	21802.496	3D	+1007	3.209	0	- 40
18477.601	2E	+ 593	0.250	+182	- 18	21804.503	5D	"	5.216	- 33	+107
18479.576	3E	"	2.225	+152	- 4	22141.581	4D	+1049	5.286	- 33	+113

To Professor Bailey's period of 8.024 days, no correction seems to be indicated. The earliest plate, dating from 1892, is discordant, but it was taken with a single prism and shows the doubling imperfectly; and the material of date later than 1906 is inadequate for determination of correction or change of period.

The preliminary curve of velocity gave, as a mean of values obtained by the usual formulæ, an angle of periastron of 287° and an eccentricity of 0.5. From Professor King's standard velocity curves, however, it appears that the curve for the periastron at 290° and eccentricity of 0.5 more nearly satisfies the observations. This curve is accordingly adopted, and is shown in the figure, where the estimates are plotted as dots and the measures as crosses.

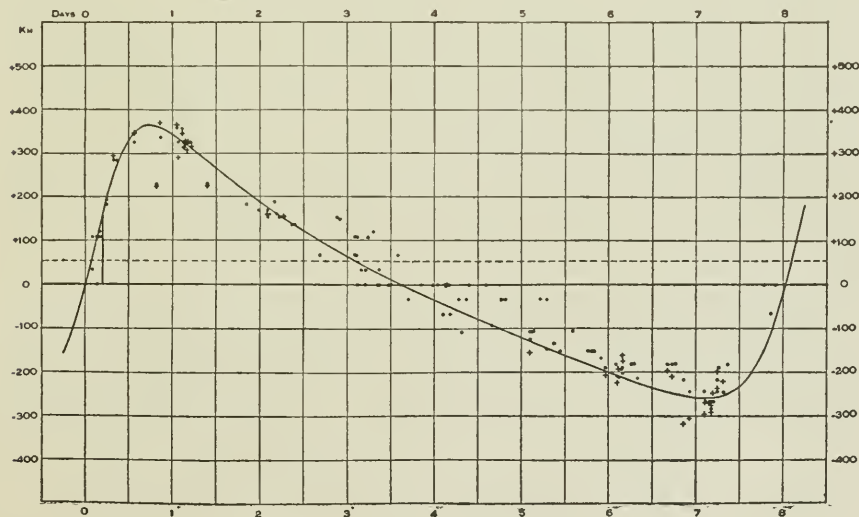
VELOCITY CURVE OF ζ CENTAURI

TABLE II
VELOCITY FROM MEASURES

J. D.	Des.	Phase	Velocity	O-C	J. D.	Des.	Phase	Velocity	O-C	J. D.	Des.	Phase	Velocity	O-C
2400000+		Days	Km	Km	2400000+		Days	Km	Km	2400000+		Days	Km	Km
12267.599	4C	0.824	+222	-140	14817.584	4B	7.201	-247	+12	14835.637	5A	1.182	+327	+9
14482.533	4B	1.134	+314	-10	14819.569	5A	1.162	+308	-12	14872.519	5F	5.968	-207	-8
14793.493	4C	7.182	-276	-16	14820.495	5C	2.088	+158	-16	15924.628	5B	6.933	-304	-48
14795.487	5A	1.152	+322	+1	14827.480	5A	1.049	+365	+26	15926.576	5A	0.857	+370	+10
14800.496	5C	6.161	-162	+49	14827.595	5A	1.164	+326	+6	15940.604	4C	6.861	-319	-66
14801.496	5B	7.161	-271	-11	14827.649	5A	1.218	+315	+5	16166.773	5B	0.334	+294	+38
14809.612	4C	7.253	-199	+58	14832.546	5B	6.115	-193	+17	16309.523	4F	6.676	-198	+48
14809.679	5B	7.320	-221	+32	14832.590	5C	6.159	-176	+34	16335.514	4C	0.571	+347	-2
14811.496	5A	1.113	+346	+18	14833.537	5B	7.106	-270	-10	17066.524	4F	1.397	+226	-55
14812.650	4F	2.267	+152	+2	14833.609	5A	7.178	-291	-31	18506.521	4F	5.098	-155	-25
14816.488	4C	6.105	-224	-15	14833.678	5C	7.247	-237	+20	21011.644	3F	6.733	-210	+39
14817.488	4C	7.105	-296	-36	14835.527	4B	1.072	+291	-43					

The corresponding elements of the relative orbit are:

$$P = 8.024 \text{ days}$$

$$T = \text{J. D. } 2413719.321$$

$$\omega = 290^\circ$$

$$e = 0.5$$

$$K + K_1 = 312 \text{ km}$$

$$(a + a_1) \sin i = 29,800,000 \text{ km}$$

$$(m + m_1) \sin^3 i = 16.4 \odot$$

The above time of periastron is 0.202 days later than the epoch from which the phases are computed. The scattering of the observations at the second zero point is explained by the long duration of the single phase, here increased by the slow motion at apastron. A like explanation applies to many of the large residuals in Table I.

An effect of approach and recession upon the spectra was found in this binary, similar to that seen in μ^1 Scorpii and V Puppis but less in degree. The lines are strengthened by approach, the ratio of intensity of those of the faint star to those of the bright being nearly two-tenths greater in approach than in recession.

The mean width of the helium lines 4388 and 4472 is about 3.6 Å, and of H γ , 3.8 Å, as against 4.6 Å and 5.5 Å in μ^1 Scorpii, a system of the same mass and spectral class but shorter period. If we assume the usual synchronism of rotation and revolution for these close binaries, this difference in width of lines appears to be due to the difference in axial rotation.

The binary ζ Centauri is another system in the class of μ^1 Scorpii, V Puppis, and Y Cygni, all remarkable for high velocity and great mass.

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CIRCULAR 234

PHOTOGRAPHIC WORK AT AREQUIPA WITH THE BRUCE 24-INCH REFRACTOR. N. G. C. 3201

BY SOLON I. BAILEY

THE Bruce telescope, after several years of comparative inactivity, has been brought again into efficient use. Photographs have been made recently, having exposures of from twenty minutes to four hours, on which the form and definition of the stellar images are satisfactory. A large field of valuable work is thus possible for this instrument. Aside from the investigation of special problems, such as the variable stars in the Magellanic Clouds and the globular clusters, standard exposures of one, two, and in some cases of four hours, taken in connection with early plates with the same instrument, will render possible a comparison of very faint celestial objects at different epochs.

In H.A. 76, No. 4, attention was called to a large number of interesting globular clusters of which no examination had been made at that time. Later, in H. C. 211, a list of globular clusters was given of which photographs were especially needed. Probably this need will be satisfied rapidly for all southern clusters by the work now in progress with the Bruce telescope.

When the photography of the southern globular clusters was first undertaken at the Arequipa Observatory about thirty years ago by the writer, the instrument chiefly employed was the Boyden refractor of thirteen inches aperture and sixteen feet focal length. That instrument has an excellent Clark lens, and the definition, on the photographs which can be made with it, leaves little to be desired. While the definition on the Bruce plates is somewhat inferior to that on the plates made with the Boyden telescope, the photographs now obtained give sufficiently good results except for stars near the centers of dense globular clusters, and the saving in time is very great. For faint clusters an exposure of nearly two hours is necessary with the Boyden telescope, while little more than one fourth as long an exposure is required with the Bruce.

The present work with the Bruce 24-inch is well illustrated by a series of about forty photographs recently obtained of N. G. C. 3201. An examination of this cluster on a few plates obtained with the Boyden 13-inch telescope was made several years ago by Miss Ida E. Woods, and the results are published in H. C. 216. For a further discussion additional plates were needed. The results already obtained by Miss Woods make this cluster one of the most interesting in the sky. Fifty-one variable stars were found within a radius of 8' from the center among 527 stars. If we exclude the stars not belonging to the cluster, but only projected upon it, the results are still more striking. A count of the number of stars in a circle of equal area just beyond the limits of the cluster, at a distance of 30', north, east, south, and west, gave 81, 106, 75, and 119 stars, respectively, or a mean of 95 stars. Assuming that the same number is projected on the cluster, 432 stars remain of those examined by Miss Woods that are really members of the system. Among these more than one in nine is variable. This ratio is exceeded, probably, only in the case of Messier 3.

The statement was made in H. C. 216 regarding N. G. C. 3201 that "it is so open a cluster that practically all of the stars are well separated even at the center." While this is true for the stars shown on the 13-inch plates and examined by Miss Woods, the statement should be modified when reference is made to all the stars in the cluster. Exposures of two and four hours with the Bruce telescope reveal a background of many hundreds of very faint stars which are somewhat condensed near the center. The 13-inch photographs gave no indication of the existence of the faint stars. These results appear to show a relative paucity of stars of intermediate magnitudes. A similar appearance has been observed by several astronomers in different clusters.

A comparison of several hundred of the faint stars on two photographs gave no indication of variability. Incidentally, however, during the comparison, five new variables were found among the brighter stars to which the numbers 57 to 61 have been assigned. Their rectangular coordinates are approximately: 57, $x + 288''$, $y - 72''$; 58, $x + 346''$, $y - 80''$; 59, $x - 490''$, $y - 70''$; 60, $x - 850''$, $y + 95''$; 61, $x - 1125''$, $y + 175''$. These variables are all somewhat distant from the center.

It appears to be of some importance to determine at how great a distance from the centers real members of such clusters can be found, thus getting a clue to the extreme diameters of such systems. The N. G. C. gives the dia-

meter of No. 3201 as 8'. A count of the stars would perhaps make the diameter 20' or 25'. Miss Woods, however, found one variable at a distance of 19' from the center, and others nearly as remote. Of the variables recently added, No. 61 is also at a distance of 19'.

From the known characteristics of such variables it appears almost certain that they belong to the cluster, in spite of their great distance, unless we assume that some process of disintegration has been at work by which members of the system have wandered away and become lost to the cluster while retaining their Cepheid character. Many hundreds of stars have been examined on several photographs of N. C. G. 3201 at distances greater than 19', but no case of variation has been found. There can be little doubt, therefore, that the extreme diameter of this cluster is about 38'. It is also evident that the number of remote members of the clusters is probably greater than is indicated by the variable stars found, since even in N. G. C. 3201 only one star in nine is variable.

MAY 25, 1922



HARVARD COLLEGE OBSERVATORY

CIRCULAR 235

OBSERVED MAXIMA AND MINIMA OF VARIABLE STARS FOR 1921

By LEON CAMPBELL

THE systematic monthly contribution of observations of long period variables, by members of the several variable star associations, as well as by other individuals and observatories, has resulted in the accumulation at Harvard of a vast amount of information on the photometry of these important stars. Between 20,000 and 25,000 observations have been received each year, the greater part appearing in the columns of Popular Astronomy and being reprinted later as the annual report of the American Association of Variable Star Observers.

Not only has this material permitted the classification of these stars according to magnitude for each month, as published in the Harvard Bulletins, but it has made possible the predictions, with a fair degree of certainty, of the times of maxima and minima for each succeeding year. The annual predictions have appeared in the Harvard Circulars since 1916.

With this data of past years at hand, it has been possible to derive mean light curves for a majority of the long period variable stars. The large amount of information on the periods and light variations, which has been obtained from the discussion of some hundred and fifty thousand observations, will soon be ready for publication in the Annals of this Observatory.

With the aid of the mean light curves the actual dates of maxima and minima can be determined systematically from the new observations as received, and it is now proposed to publish annually the observed dates in order that more prompt information may be available.

The following table contains the observed dates for 1921. The designation number and name of each variable appear in the first and second columns, respectively. The name of the constellation is abbreviated in accordance with the table printed in H.B. 771. The observed magnitude and date of maximum are given in the third and fourth columns, followed by the

OBSERVED MAXIMA AND MINIMA

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
000339	V Scl	9.0	242	4	295	..	242	2	306	021281	Z Cep	..	242	..	<15	242	2	285	
001032	S Scl	6.3	3037	5	358	12.3	2875	4	357	021403	o Cet	..	2822	3	314	9.5	2717	5	331
001046	X And	9.3	3023	5	341	..	2890	2	359	"	"	..	..	..	9.6	3052	5	335	
001726	T And	8.1	2736	3	273	..	2898	2	289	021558	S Per	8.7	2996	4	756	..	..	..	..
"	"	8.3	3023	5	287	..	..	..	..	022000	R Cet	8.0	2707	4	159	..	2790	3	161
001755	T Cas	7.6	2770	5	438	11.8	2972	5	444	"	"	8.0	3027	5	..	..	2954	2	164
001838	R And	7.3	3055	5	374	14.2	2915	4	383	022150	RR Per	9.3	2723	5	395	14.5	2925	3	375
001862	S Tuc	9.4	2899	4	248	14.0	2798	4	238	022426	R For	9.5	2910	4	388	13.0	2723	5	389
"	"	..	..	..	..	14.2	3040	3	242	022813	U Cet	7.2	2894	4	228	..	2784	3	237
001909	S Cet	..	2778	3	354	14.7	2944	2	343	"	"	..	..	..	12.6	3025	5	241	
002438a	T Scl	..	2774	2	202	..	..	..	..	022980	RR Cep	9.8	2844	5	387	..	..	..	..
"	"	..	2974	2	200	..	..	..	..	023133	R Tri	..	2810	4	269	11.8	2966	5	282
002546	T Phe	..	2792	4	294	..	2942	3	260	024356	W Per	..	..	..	10.6	2860	4	422	
003179	Y Cep	..	2826	2	333	16.0	3015	4	328	025050	R Hor	4.7	2837	5	387	..	..	..	..
004047	U Cas	8.8	2733	5	285	..	2864	3	256	025751	T Hor	8.0	2841	5	213	13.2	2730	5	213
"	"	8.2	3010	5	277	..	..	..	..	"	"	8.2	3054	5	213	13.0	2953	4	223
004132	RW And	..	2853	3	444	..	..	..	..	030514	U Ari	..	2815	4	370	15.0	3038	3	386
004435	V And	9.7	2912	4	253	..	2797	3	238	031401	X Cet	8.9	2740	5	170	..	2838	2	178
"	"	..	..	..	..	13.8	3052	4	255	"	"	8.9	2913	4	173	12.0	3013	5	175
004435	X Scl	..	2852	3	254	..	2732	3	252	032043	Y Per	8.4	2759	5	249	10.2	2884	5	253
"	"	..	..	..	..	..	2990	2	258	"	"	8.3	3024	5	265	..	..	..	..
004533	RR And	..	2770	2	342	14.3	2920	2	289	032335	R Per	8.8	2895	4	213	..	2795	3	210
004746a	RV Cas	8.8	2738	5	326	15.0	2957	4	333	"	"	..	..	..	13.8	3004	5	209	
004958	W Cas	..	..	..	..	11.3	2899	5	415	034625	U Eri	..	2830	2	282	..	..	..	..
005475	U Tuc	8.5	2751	5	263	14.0	2907	4	259	035124	T Eri	7.9	2923	2	256	12.2	2777	3	211
"	"	8.2	3020	5	269	..	..	..	..	042209	R Tau	8.5	2954	4	316	..	2828	3	321
010102	Z Cet	9.0	2972	3	..	..	2701	3	..	042215	W Tau	9.6	2780	4	256	13.0	2896	3	244
010630	U Scl	9.8	2737	5	328	..	2972	2	342	"	"	9.3	3052	5	272	..	..	..	..
010940	U And	10.2	2883	3	354	14.0	2728	2	351	042309	S Tau	..	2860	1	376	15.5	3050	3	370
011041	UZ And	10.5	2863	3	319	14.0	2754	2	326	043065	T Cam	7.8	2842	5	380	13.7	3050	5	368
011208	S Psc	..	2914	3	400	14.8	2774	3	406	043208	RX Tau	..	2878	4	338	14.5	2717	5	337
011272	S Cas	8.7	3046	5	628	15.0	2760	4	591	043263	R Ret.	7.3	2764	5	274	13.0	2928	4	282
011712	U Psc	11.0	2976	4	..	15.0	2698	3	170	"	"	7.7	3040	5	276	..	..	..	..
"	"	..	..	..	..	..	2872	2	174	043274	X Cam	7.9	2804	5	151	12.8	2732	5	144
012350	RZ Per	10.2	2792	4	360	..	3012	2	347	"	"	8.0	2944	5	140	..	2868	4	136
012502	R Psc	..	2868	3	338	..	2728	3	366	"	"	..	..	..	13.1	3014	5	146	
013238	RU And	10.3	2902	5	217	..	2802	3	234	043562	R Dor	5.2	2919	4	369	6.1	2748	4	175
"	"	..	..	..	..	14.0	3010	4	208	043738	R Cae	8.0	2691	5	389	13.0	2938	5	401
013338	Y And	8.5	2770	4	214	..	2892	3	222	044349	R Pic	..	2698	3	..	..	..	..	..
"	"	8.6	3000	5	230	..	..	..	..	044617	V Tau	9.0	2730	3	178	..	2812	1	173
014958	X Cas	10.4	2707	5	415	12.8	2882	4	424	"	"	..	2890	3	160	13.8	2978	4	166
015354	U Per	8.0	2790	4	328	10.6	2965	5	317	045307	R Ori	..	2874	3	376	12.5	2714	5	370
015912	S Ari	11.0	2974	5	290	..	2838	2	296	045514	R Lep	..	2872	3	413	10.2	3043	4	423
021024	R Ari	..	2816	4	194	13.3	2716	5	184	050003	V Ori	9.0	2793	3	287	..	2923	3	268
"	"	7.9	2990	5	174	12.8	2908	5	192	050022	T Lep	8.6	2723	5	371	13.0	2924	5	369
021143a	W And	7.8	2942	5	393	13.6	2778	4	394	050848	S Pic	9.0	2954	5	437	..	2790	3	415
021281	Z Cep	11.0	2896	3	288	<15	2762	2	284	050953	R Aur	8.5	2933	5	479	13.9	2695	5	483

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
051247	T Pic	8.7	2832	5	200	14.0	2731	4	189	074241	W Pup	8.8	2802	4	121	12.5	2744	4	121
"	"	8.2	3032	5	200	14.0	2951	4	220	"	"	8.0	2921	4	119	12.6	2863	4	119
051533	T Col	6.6	2770	5	214	12.4	2891	4	225	"	"	7.5	3043	4	122	..	2982	3	119
"	"	8.0	2998	5	228	..	..	..	..	074323	T Gem	8.5	2808	4	306	..	2969	3	297
052034	S Aur	8.6	2880	4	540	..	..	..	..	074922	U Gem	9.3	2769	5	87	14.0	2725	4	79
052036	W Aur	8.8	2893	4	264	13.5	2770	5	248	"	"	9.1	2990	4	..	14.0	3035	4	..
052404	S Ori	..	2890	3	416	..	..	..	..	081112	R Cnc	7.6	2781	4	356	11.8	2960	4	358
053068	S Cam	8.3	2747	5	335	10.5	2901	5	333	081617	V Cnc	7.8	2816	4	281	..	2951	3	267
"	"	8.5	3048	5	301	..	..	..	..	082476	R Cha	7.4	2961	5	340	13.5	2807	4	327
053531	U Aur	9.4	2775	4	417	15.5	3030	4	416	083019	U Cnc	..	2932	3	287	15.0	2829	3	299
054331	S Col	9.6	2977	5	326	..	2817	3	305	083350	X UMa	8.1	2781	5	..	..	2931	3	251
054615a	Z Tau	..	..	..	..	14.0	2900	4	510	"	"	..	3030	4	249	..	..	..	..
054629	R Col	8.8	3000	4	331	..	2860	3	328	084803	S Hya	..	2906	3	260	12.8	2778	4	272
054920	U Ori	5.6	2888	4	364	11.9	2763	5	378	"	"	..	..	..	..	14.0	3037	5	259
054974	V Cam	10.6	2950	5	529	..	2809	3	515	085008	T Hya	..	2878	3	294	13.1	2737	4	307
055353	Z Aur	9.2	2705	4	102	10.9	2756	4	90	"	"	..	..	..	..	12.7	3028	5	291
"	"	9.5	2805	4	100	10.9	2871	4	115	090024	S Pyx	8.7	2723	5	..	..	2823	3	208
"	"	9.3	2934	4	129	11.2	2979	4	108	"	"	..	2917	1	194	..	3030	1	207
"	"	9.4	3033	4	99	..	..	..	..	090425	W Cnc	8.3	3031	5	401	14.5	2881	3	402
055686	R Oct	7.8	2944	4	404	11.0	2750	4	408	091868	RW Car	9.1	2700	5	311	..	2884	3	309
060450	X Aur	8.4	2818	4	174	11.8	2725	5	167	"	"	9.1	3019	4	319	..	..	..	..
"	"	8.3	2976	4	158	..	2890	3	165	092551	Y Vel	9.8	3044	4	474	13.5	2850	4	470
"	"	..	..	..	..	12.8	3047	4	157	092962	R Car	5.0	2868	5	316	9.8	2733	5	315
060547	SS Aur	11.0	2738	5	69	..	2706	4	65	"	"	..	..	..	..	9.5	3038	5	305
"	"	10.7	2809	5	71	14.8	2774	5	68	093014	X Hya	9.3	2722	4	300	..	2908	1	310
"	"	10.6	2969	5	..	15.0	3005	5	..	"	"	..	3014	1	292	..	..	..	..
"	"	10.9	3031	5	62	..	..	..	..	093178	Y Dra	8.7	2982	5	330	14.5	2838	3	346
061647	V Aur	..	2944	1	350	11.6	2781	3	368	093934	R LMi	7.2	2749	5	379	13.0	2973	4	363
061702	V Mon	..	2880	2	343	13.4	2722	4	334	094023	RR Hya	..	..	..	..	..	2852	3	336
063159	U Lyn	..	2910	3	416	14.4	2728	5	455	094211	R Leo	5.8	2700	5	296	10.5	2883	4	305
063558	S Lyn	9.8	2970	4	300	..	2848	2	318	"	"	5.7	3027	5	327	..	..	..	..
064030	X Gem	8.0	2921	3	266	13.1	2784	4	244	094953	Z Vel	9.3	2861	5	421	..	..	..	..
065111	Y Mon	..	2890	2	220	13.4	2772	3	227	095421	V Leo	8.6	2760	5	270	..	2906	3	274
"	"	..	..	..	..	13.2	3008	4	236	"	"	..	3026	4	266	..	..	..	..
065208	X Mon	7.0	2700	3	..	9.2	2760	4	..	095458	RR Car	7.4	2766	4	166	8.1	2852	4	170
"	"	7.2	2980	4	280	..	..	..	..	"	"	7.4	2936	3	170	..	..	..	..
065355	R Lyn	7.8	2848	5	398	14.0	3042	4	370	095563	RV Car	11.2	2795	4	357	..	..	..	..
070109	V CMi	8.3	2975	2	365	..	2847	3	371	100661	S Car	5.1	2818	4	150	8.5	2739	5	149
070122a	R Gem	7.0	3004	5	378	..	2860	3	376	"	"	5.0	2962	4	144	7.5	2878	5	139
070310	R CMi	8.1	2731	5	333	11.6	2919	4	356	"	"	..	..	..	..	8.8	3033	5	155
070772	R Vol	10.1	2792	4	420	..	3012	1	430	101058	Z Car	11.0	2943	4	373	..	2800	3	390
071201	RR Mon	..	2922	1	414	..	2750	1	392	011153	W Vel	8.3	2890	5	399	13.8	2721	4	380
071713	V Gem	..	2908	3	251	14.5	2799	5	333	103270	RZ Leo	10.0	2951	3	287	..	2828	3	275
072708	S CMi	..	2872	4	329	12.7	2706	5	335	103769	R UMa	7.0	2963	5	300	12.9	2833	5	287
"	"	..	..	..	..	13.0	3042	5	336	104620	V Hya	6.2	2950	4	470	7.8	2730	4	526
072811	T CMi	9.6	2765	4	309	..	2966	3	316	104628	RS Hya	..	2973	3	327	14.8	2844	4	356
072820b	Z Pup	7.5	2725	4	531	..	..	..	..	104814	W Leo	9.6	2718	5	382	14.0	2980	3	380
073173	S Vol	8.9	3000	5	394	13.7	2800	4	404	110506	S Leo	10.0	2744	4	..	..	2832	2	188
073508	U CMi	8.5	2953	4	413	13.4	2776	4	432	"	"	..	..	..	..	14.0	3008	3	176
073723	S Gem	8.9	2779	4	281	..	2950	3	281	111661	RS Cen	7.6	2729	5	147	13.5	2821	4	153

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
111661	RS Cen	9.2	2911	4	182	..	2984	3	163	141567	U UMi	7.8	2836	5	333	11.8	3006	5	334
114441	X Cen	8.1	2775	5	307	13.4	2960	4	299	141954	S Boo	8.2	2712	5	270	13.0	2853	5	270
115058	W Cen	8.2	2849	5	206	13.3	2750	4	200	"	"	8.1	2980	5	268	..	..	..	..
"	"	8.4	3048	4	199	13.5	2965	3	215	142205	RS Vir	8.5	2793	5	354	..	3020	3	352
115919	R Com	8.2	2860	5	368	..	2730	3	366	142539	V Boo	7.0	2885	5	263	10.5	2767	5	257
120012	SU Vir	..	2897	1	212	13.4	2788	4	200	"	"	..	..	..	..	10.3	3030	5	263
120905	T Vir	..	2951	2	356	14.5	2789	3	316	142584	R Cam	8.1	2933	5	282	13.3	2800	4	270
121418	R Crv	7.6	2838	4	308	13.5	2718	3	310	143227	R Boo	7.1	2826	5	218	12.5	2727	4	225
"	"	..	..	..	..	..	3038	3	320	"	"	..	..	..	..	12.8	2946	5	219
122001	SS Vir	6.0	2998	4	364	9.3	2818	5	371	143417	V Lib	..	2877	3	241	..	2791	4	267
122532	T CVn	9.0	2740	5	290	11.9	2892	5	275	144918	U Boo	10.3	2722	4	190	12.3	2793	4	188
"	"	8.8	3010	5	270	..	..	..	..	"	"	9.9	2902	5	180	13.0	2992	4	199
122803	Y Vir	9.5	2884	4	224	14.2	2787	4	220	145254	Y Lup	..	..	..	..	..	2910	3	406
"	"	..	..	..	..	..	3003	3	216	150018	RT Lib	9.0	2866	5	256	..	2758	2	250
122854	U Cen	8.7	2776	5	219	13.7	2883	4	215	"	"	..	..	..	..	..	3020	3	262
"	"	8.0	3000	4	224	..	..	..	..	150519	T Lib	11.2	2802	5	240	..	2703	3	251
123160	T UMa	6.9	2793	5	245	13.0	2950	5	276	"	"	..	3033	3	231	..	2941	2	238
123307	R Vir	6.9	2781	5	150	12.0	2711	4	153	150605	Y Lib	9.0	2818	5	274	..	2706	3	261
"	"	6.8	2921	4	140	11.0	2850	5	139	"	"	..	..	..	..	..	2987	4	281
"	"	..	..	..	..	..	2990	3	140	151520	S Lib	8.5	2798	4	188	..	2694	3	198
123459	RS UMa	8.7	2940	5	265	14.0	2827	4	279	"	"	..	2998	2	200	12.4	2897	4	203
123961	S UMa	7.7	2897	5	227	11.5	2791	5	221	151714	S Ser	8.5	2923	5	365	13.8	2783	4	385
"	"	..	..	..	..	11.7	3018	5	227	151731	S CrB	7.3	2704	5	362	13.0	2948	5	366
124204	RU Vir	..	..	..	..	14.4	2780	2	..	151822	RS Lib	7.5	2750	4	222	12.0	2869	5	226
124606	U Vir	8.1	2839	5	208	13.6	2744	4	200	"	"	8.5	2978	4	228	..	..	..	..
"	"	8.0	3036	3	197	..	2958	2	214	152714	RU Lib	7.3	2899	5	325	..	2761	3	314
130212	RV Vir	11.2	2761	3	275	..	..	..	..	152849	R Nor	7.0	2870	5	390	..	..	..	..
131283	U Oct	7.8	2820	5	300	13.6	2998	5	324	153020	X Lib	11.4	2823	2	170	..	2755	1	169
132202	V Vir	9.2	2736	4	251	14.5	2898	3	258	153215	W Lib	11.9	2877	3	..	..	2768	2	220
132422	R Hya	4.0	3048	5	410	9.7	2836	5	402	"	"	..	..	..	..	..	2974	2	206
132706	S Vir	6.5	2733	4	366	..	2927	3	369	153378	S UMi	8.1	2930	5	328	11.4	2766	5	327
133155	RV Cen	7.3	2712	5	452	10.4	2911	5	442	153620a	U Lib	..	2816	3	252	..	2932	1	245
133273	T UMi	9.6	2968	4	328	13.8	2825	4	325	153654	T Nor	7.6	2758	4	242	12.8	2909	4	251
133633	T Cen	6.0	2693	4	83	7.6	2741	4	79	"	"	..	3002	2	244	..	..	..	..
"	"	6.0	2788	4	95	8.5	2837	4	96	154428	R CrB	6.2	2815	4	..	9.3	2767	5	..
"	"	6.3	2882	4	94	7.5	2932	4	95	"	"	6.3	2900	4	85	7.4	2855	4	88
"	"	6.0	2973	4	91	..	3016	4	84	"	"	..	..	..	..	9.6	2976	5	121
"	"	6.0	3052	4	79	..	..	..	..	154536	X CrB	..	2717	3	239	13.5	2856	5	256
134236	RT Cen	8.1	2938	5	251	12.6	2814	4	253	"	"	9.2	2957	5	240	..	..	..	..
134440	R CVn	7.5	2828	5	326	11.8	3000	5	324	154615	R Ser	6.8	2757	4	353	12.9	2968	4	364
134536	RX Cen	9.2	2748	5	328	..	2960	3	329	154639	V CrB	7.1	3004	5	346	10.8	2846	5	358
134677	T Aps	8.5	2828	5	258	..	2728	4	267	154715	R Lib	..	2800	4	227	..	2918	2	..
"	"	..	..	..	..	..	2993	3	265	"	"	..	3048	1	248	..	..	..	..
135908	RR Vir	12.0	2718	3	234	..	2835	3	223	154736	R Lup	..	2712	3	240	..	2813	2	230
"	"	11.7	2926	3	208	..	3050	3	215	"	"	9.8	2922	3	210	..	..	..	..
140113	Z Boo	9.1	2828	5	284	..	2728	3	280	155018	RR Lib	..	2703	3	276	14.1	2851	4	269
"	"	..	..	..	..	..	3004	3	276	"	"	8.8	2969	3	266	..	..	..	..
140512	Z Vir	..	..	..	..	..	2833	4	322	155229	Z CrB	..	2700	3	243	15.0	2825	3	241
140528	RU Hya	7.6	2887	4	335	14.0	2737	4	323	"	"	9.7	2943	3	243	..	..	..	..
140959	R Cen	..	..	..	..	11.9	2847	5	563	155823	RZ Sco	..	2699	2	158	12.8	2772	3	152

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
					242				242						242				d
155823	RZ Sco	8.7	2850	5	151	12.5	2933	3	161	147135	SV Sco	9.9	2966	4	246	..	..	..	..
160021	Z Sco	..	3023	4	333	12.3	2893	4	367	174162	W Pav	9.2	2847	5	287	..	2740	4	292
160118	R Her	8.5	2851	5	315	..	2722	4	304	"	"	..	..	..	..	..	3013	3	273
"	"	..	..	..	..	15.0	3038	4	316	174551	U Ara	8.2	2729	3	213	..	2862	3	210
160210	U Ser	8.5	2824	5	236	..	2719	3	231	"	"	8.5	2950	3	221	..	..	..	..
"	"	8.0	3050	3	226	12.6	2958	3	239	175111	RT Oph	..	3051	3	440	<15	2859	3	429
160221a	X Sco	..	2764	1	214	..	2860	1	202	175458a	T Dra	10.0	2878	5	428	12.4	2700	4	424
160625	RU Her	8.0	2998	4	468	13.3	2798	4	479	175519	RY Her	8.3	2864	5	226	13.7	2763	4	213
161122a	R Sco	11.2	2778	4	235	15.5	2893	4	205	"	"	..	..	..	..	14.0	2990	4	227
"	"	..	3000	3	222	..	..	..	..	175654	V Dra	9.8	2750	2	278	14.2	2886	4	272
161122b	S Sco	10.3	2798	5	166	..	2711	3	171	"	"	9.6	3020	4	270	..	..	..	..
"	"	9.9	2970	4	172	..	2884	4	173	180363	R Pav	8.1	2692	4	226	13.0	2812	3	224
161138	W CrB	8.4	2732	3	223	13.0	2872	5	229	"	"	7.5	2925	4	233	..	..	..	..
"	"	8.3	2970	5	238	..	..	..	..	180531	T Her	8.1	2699	4	168	12.8	2791	5	169
161607	W Oph	9.3	2820	4	332	..	3010	3	322	"	"	8.5	2868	5	169	12.8	2954	5	163
162112	V Oph	..	2740	3	285	10.2	2850	5	260	"	"	7.8	3031	5	163	..	..	..	..
"	"	7.8	3030	4	290	..	..	..	..	180565	W Dra	10.1	2693	4	261	..	2840	2	253
162119	U Her	..	..	..	..	12.3	2916	5	408	"	"	9.0	2950	4	257	..	..	..	..
162319	Y Sco	11.6	2938	3	343	..	..	..	..	180666	X Dra	11.5	2848	3	272	..	2745	2	295
162807	SS Her	9.2	2787	4	110	12.6	2738	3	112	"	"	..	..	..	..	15.0	3004	3	259
"	"	9.3	2887	5	100	12.8	2840	4	102	181031	T V Her	9.0	3030	3	..	..	..	..	..
"	"	9.3	2988	4	101	12.0	2940	5	100	181103	RY Oph	7.9	2790	5	150	13.0	2730	4	157
"	"	..	..	..	..	13.0	3054	4	114	"	"	8.9	2938	5	148	13.6	2878	5	148
162815	T Oph	9.7	2800	3	365	..	3018	3	..	"	"	..	..	..	..	13.6	3020	4	142
162816	S Oph	10.4	2870	4	..	..	..	..	..	181136	W Lyr	7.7	2863	5	195	12.3	2776	5	200
163137	W Her	8.4	2903	5	275	13.5	2766	5	266	"	"	..	..	..	..	11.8	2964	5	188
"	"	..	..	..	..	13.0	3045	4	270	182133	RV Sgr	8.0	2939	4	315	14.5	2778	4	313
163266	R Dra	6.9	2907	5	230	12.5	2808	5	249	182224	SV Her	9.5	2720	4	231	14.5	2869	5	257
164319	RR Oph	..	2708	2	290	13.1	2866	5	285	"	"	9.8	2965	5	245	..	..	..	..
"	"	8.5	3000	3	292	..	..	..	..	182306	T Ser	9.5	2772	4	355	..	2974	3	342
164715	S Her	7.6	2773	5	299	12.1	2928	5	301	183149	SV Dra	..	2746	3	254	..	2890	3	247
164844	RS Sco	6.2	2960	5	318	12.4	2849	4	329	"	"	9.7	3000	4	254	..	..	..	..
165030	RR Sco	5.9	2820	5	286	11.3	2969	4	279	183225	RZ Her	9.8	2774	4	324	15.0	2936	4	300
165202	SS Oph	..	2719	2	170	..	2819	3	186	183308	X Oph	6.6	2831	5	355	8.9	2974	5	335
"	"	9.0	2909	4	190	..	3000	1	181	184134	RY Lyr	10.4	2853	4	327	<15	2702	3	322
165631	RV Her	10.9	2770	5	197	..	2890	4	208	"	"	..	..	..	..	<15	3047	4	345
"	"	10.8	2978	4	208	..	..	..	..	184205	R Set	5.3	2746	4	121	7.7	2808	5	113
165636	RT Sco	..	..	..	..	..	2953	3	453	"	"	5.2	2858	5	112	6.3	2940	5	132
170215	R Oph	7.2	2780	4	302	12.7	2940	3	301	"	"	5.1	2989	5	131	6.3	3030	5	90
170627	RT Her	8.8	2762	4	284	15.0	2936	4	300	184243	RW Lyr	11.2	2885	4	510	15.5	2691	3	521
170833	RW Sco	..	2723	3	370	..	3008	3	392	185032	RX Lyr	12.0	2712	4	250	<15	2870	3	263
171401	Z Oph	8.0	2716	4	353	12.3	2935	5	352	"	"	12.8	2976	3	264	..	..	..	..
171723	RS Her	8.4	2746	4	225	12.6	2867	4	215	185512a	ST Sgr	..	..	..	..	..	2904	2	..
"	"	7.9	2962	5	216	..	..	..	..	185634	Z Lyr	..	2733	3	307	15.0	2889	4	302
172486	S Oct	8.0	2863	5	262	13.6	2773	4	270	"	"	10.5	3013	5	280	..	..	..	..
"	"	..	..	..	..	13.3	3021	4	248	185737	RT Lyr	..	2716	2	250	14.5	2867	3	250
172809	RU Oph	9.4	2824	4	202	13.5	2727	4	193	"	"	10.0	2972	4	256	..	..	..	..
"	"	..	3026	3	202	13.7	2926	5	199	190108	R Aql	5.8	2933	5	306	11.7	2813	4	307
173543	RU Sco	7.8	2998	5	351	12.8	2810	5	362	190529a	V Lyr	10.0	2808	4	374	15.0	2700	3	384
174135	SV Sco	9.7	2720	3	254	..	2863	3	253	190819b	RX Sgr	..	2743	2	350	..	..	..	..

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
190925	S Lyr	11.3	²⁴² 2747	4	<i>d</i>	14.5	²⁴² 3050	4	<i>d</i>	200938	RS Cyg	7.2	²⁴² 3010	4	410	8.6	²⁴² 2833	4	394
190933a	RS Lyr	..	2746	3	286	..	2900	3	289	201008	R Del	8.4	2960	5	291	13.6	2824	4	285
"	"	10.5	3035	4	289	..	..	..	..	201130	SX Cyg	..	2729	3	429	14.5	2981	4	418
190941	RU Lyr	11.2	3010	3	373	15.0	2841	3	353	<i>201139</i>	RT Sgr	6.0	2801	4	294	..	2973	4	302
190967	U Dra	9.6	2758	3	305	13.8	2932	4	302	201647	U Cyg	7.2	2700	5	480	11.1	2941	5	471
191007	W Aql	8.5	2943	4	447	..	2792	3	450	<i>202240</i>	U Mic	8.7	2808	4	332	14.0	2694	4	328
191017	T Sgr	..	2822	2	392	..	3026	2	401	"	"	..	..	..	..	..	3030	3	336
191019	R Sgr	..	2691	3	265	12.1	2820	4	256	<i>202622</i>	RU Cap	9.2	2888	4	343	..	2780	3	360
"	"	7.5	2950	5	259	..	..	..	..	202817	Z Del	9.5	2853	4	293	..	2723	3	299
<i>191124</i>	TY Sgr	9.6	2799	4	321	..	2691	3	327	"	"	..	..	..	..	14.5	3030	3	307
"	"	..	..	..	..	..	3015	3	324	202954	ST Cyg	10.4	2803	5	325	14.0	2998	4	327
191319	S Sgr	9.9	2926	5	..	..	2820	3	250	<i>203429</i>	R Mic	9.2	2803	4	143	..	2730	3	142
191321	Z Sgr	9.5	3020	3	460	..	2852	3	456	"	"	9.4	2937	5	134	..	2871	3	141
191331	SW Sgr	..	2729	4	300	..	2880	4	292	"	"	..	..	..	..	13.5	3010	4	139
"	"	9.7	3020	4	291	..	..	..	..	203611	Y Del	8.8	3049	3	463	<14	2865	3	465
191637	U Lyr	9.7	2945	4	456	11.9	2691	4	452	203816	S Del	9.0	2810	4	254	11.3	2944	4	259
192928	TY Cyg	8.6	3040	4	355	15.0	2860	4	354	203847	V Cyg	7.9	2970	5	443	12.2	2710	5	420
193311	RT Aql	9.8	2958	4	316	..	2818	2	306	<i>203905</i>	Y Aqr	..	2860	4	370	..	2708	4	385
193449	R Cyg	6.9	2744	5	391	13.7	3030	5	447	204016	T Del	..	2720	4	315	15.0	2903	3	317
193509	RV Aql	9.9	2752	4	230	..	2876	4	219	<i>204104</i>	W Aqr	..	2748	3	372	13.9	2965	4	375
"	"	9.9	2958	5	206	..	..	..	..	<i>204215</i>	U Cap	..	2690	1	..	..	2790	2	212
<i>193972</i>	T Pav	8.4	2826	5	235	..	2719	4	249	"	"	10.9	2892	4	202	..	2996	3	206
"	"	..	..	..	..	13.6	2950	5	231	204318	V Del	9.7	2950	5	567	<15	2756	3	579
194048	RT Cyg	7.1	2708	5	186	12.3	2812	5	190	<i>204405</i>	T Aqr	8.6	2772	4	203	13.0	2879	4	207
"	"	7.3	2900	5	192	12.0	3003	5	191	"	"	8.5	2980	5	208	..	..	..	..
194348	TU Cyg	9.0	2821	5	220	..	2706	4	214	204846	RZ Cyg	10.4	2955	4	..	14.1	2798	3	..
"	"	..	..	..	..	14.5	2938	4	232	<i>204954</i>	S Ind	7.4	3015	5	397	<14	2862	3	400
"	"	9.2	3043	5	222	..	..	..	..	205017	X Del	..	2710	3	272	..	2863	3	270
194604	X Aql	..	2752	3	345	15.0	2951	4	355	"	"	8.5	2984	5	274	..	..	..	..
194632	χ Cyg	5.1	2920	5	407	13.2	2763	5	417	205923	R Vul	7.6	2764	4	138	..	2693	4	134
<i>194659</i>	S Pav	..	3040	3	397	10.1	2854	5	388	"	"	8.6	2900	5	136	13.2	2835	4	142
<i>194929</i>	RR Sgr	7.0	2762	4	337	14.0	2950	4	337	"	"	7.3	3039	5	139	12.7	2968	4	133
<i>195142</i>	RU Sgr	6.3	2700	4	238	12.5	2840	4	240	<i>210124</i>	V Cap	9.5	2752	3	281	..	2913	3	273
"	"	6.5	2943	5	243	..	..	..	..	"	"	9.1	3022	4	270	..	..	..	..
<i>195202</i>	RR Aql	..	2808	4	350	..	2704	3	363	210129	TW Cyg	10.7	2736	4	326	14.1	2899	3	329
<i>195308</i>	RS Aql	..	2874	3	379	..	2714	3	395	210382	X Cep	9.0	2945	4	521	..	2750	3	552
195849	Z Cyg	8.8	2699	5	259	14.5	2838	4	257	<i>210504</i>	RS Aqr	10.0	3040	..	..	..	..	..	..
"	"	8.1	2967	5	268	..	..	..	..	<i>210516</i>	Z Cap	9.8	2940	3	..	..	..	..	..
200212	SY Aql	9.9	2784	5	373	14.0	3012	5	368	210812	R Equ	..	2893	2	283	..	2768	2	271
200357	S Cyg	10.5	2802	4	318	..	2990	3	326	"	"	..	..	..	..	14.5	3040	3	272
<i>200514</i>	R Cap	9.8	2832	3	300	..	2704	3	..	210868	T Cep	6.0	2792	5	390	10.3	2966	5	389
"	"	..	..	..	..	..	3020	3	316	<i>210903</i>	RR Aqr	..	2925	2	..	..	..	..	..
200715a	S Aql	9.2	2730	4	145	11.7	2805	5	142	211614	X Peg	..	2750	4	185	12.9	2856	4	195
"	"	9.3	2870	4	140	11.1	2946	4	141	"	"	9.5	2958	5	208	..	..	..	..
"	"	9.5	3000	4	130	..	..	..	..	<i>212030</i>	S Mic	..	2726	4	219	..	2814	3	199
<i>200747</i>	R Tel	9.0	2834	5	460	..	..	..	..	"	"	9.7	2931	4	205	..	3020	3	206
200812	RU Aql	9.5	2932	4	268	..	2824	2	264	213678	S Cep	8.4	2882	5	486	..	..	..	..
<i>200906</i>	Z Aql	..	2769	3	111	..	2835	4	..	213843	SS Cyg	8.2	2721	5	77	11.9	2766	5	81
"	"	9.5	2900	5	131	13.6	2976	5	141	"	"	8.2	2809	5	88	11.9	2849	5	83
"	"	9.5	3034	4	134	..	..	..	..	"	"	8.5	2877	4	68	11.8	2915	5	66

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
213843	SS Cyg	8.1	2951	5	74	11.9	2989	5	74	223841	R Lac	9.1	2926	5	294	14.3	2809	4	281
"	"	8.4	3015	4	64	11.9	3055	5	66	225120	S Aqr	8.0	3055	3	..	..	2950	3	278
214024	RR Peg	9.1	2847	5	271	..	2734	3	266	225914	RW Peg	..	2756	3	197	..	2872	2	210
"	"	..	..	..	..	..	2999	3	265	"	"	9.5	2971	5	215	..	..	..	..
214247	R Gru	9.4	2702	5	335	..	2907	4	309	230110	R Peg	8.4	2744	4	390	13.0	2945	3	389
"	"	8.8	3046	4	344	..	..	..	..	230759	V Cas	7.5	2864	5	234	12.3	2757	5	231
215605	V Peg	..	2763	2	323	14.0	2929	3	321	"	"	..	..	..	..	12.6	2988	5	231
215934	RT Peg	..	2760	1	208	..	2864	1	198	231425	W Peg	8.7	2733	5	340	12.6	2917	5	339
"	"	9.8	2962	3	202	..	..	..	..	231508	S Peg	7.7	2924	4	320	13.2	2777	4	309
220412	T Peg	9.4	2848	4	358	..	2699	3	379	232746	V Phe	..	2818	3	242	13.6	2713	3	253
"	"	..	..	..	..	14.5	3050	4	351	"	"	..	..	..	..	..	..	2	262
220613	Y Peg	11.6	2977	4	..	15.0	2895	3	215	233335	ST And	8.9	2758	4	351	11.1	2920	5	336
220714	RS Peg	9.3	2879	4	402	13.6	2693	3	403	233815	R Aqr	..	..	..	..	10.4	2902	4	378
221230	R PsA	9.6	2939	2	279	..	..	..	..	233956	Z Cas	10.2	3026	5	516	..	2818	3	505
221938	T Gru	8.5	2691	4	133	..	2760	2	137	235053	RR Cas	10.9	2800	4	300	14.0	2952	4	297
"	"	8.5	2823	4	132	11.6	2895	4	135	235150	R Phe	..	2835	2	265	14.0	2712	4	282
"	"	..	2968	3	145	..	..	..	..	"	"	..	..	..	..	..	2978	1	266
221948	S Gru	7.4	2971	3	417	..	2820	3	387	235209	V Cet	8.6	2903	4	256	..	2800	3	267
222129	RV Peg	..	..	..	..	..	2798	2	400	235265	R Tuc	..	2860	2	266	..	2760	3	280
222439	S Lac	8.0	2699	5	239	13.7	2830	5	250	"	"	..	..	..	..	..	3040	2	280
"	"	8.2	2938	5	239	..	..	..	..	235350	R Cas	6.5	2968	5	426	13.0	2797	4	410
222867	R Ind	..	2775	3	..	..	2890	4	..	235525	Z Peg	8.0	2833	4	318	13.0	3000	4	324
"	"	9.1	2990	5	215	..	..	..	..	235715	W Cet	..	2738	2	..	<14	2950	2	354
223462	T Tuc	9.0	2904	3	254	..	2780	3	254	235855	Y Cas	..	..	..	..	14.8	2900	3	390
"	"	..	..	..	..	..	3040	2	260	235939	SV And	9.2	2960	4	318	..	2820	2	306

relative weight of the determination. The interval in days since the last preceding maximum is given in the sixth column. Columns seven to ten contain similar data for the observed minima.

The system of weights is an arbitrary one, on a scale of five, and is intended to indicate the reliability that can be placed on the determinations. A weight of one (1) has been assigned when the observations are very meager and comparatively little value can be attached to the result. Weight five (5) indicates a very thoroughly observed maximum or minimum. Intermediate weights have been assigned, dependent on the continuity of the curve and the number of observations at, or near, the phase in question. The magnitudes at maximum and minimum are cited only when the observations are sufficiently abundant to warrant a determination.

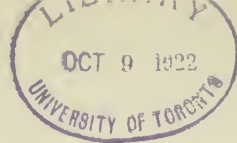
Dates of maxima and minima for such irregular variables as R Coronae Borealis, 154428, R Scuti, 184205, and SS Cygni, 213843, are included in the

above table, since for many years these stars have been very assiduously observed in nearly all longitudes. The variable SU Tauri, 054319, has been at nearly constant magnitude, 9.5, since March, 1917. RY Sagittarii, 191033, another star of the R Coronae Borealis type, has been considerably fainter than normal, since May, 1921.

A comparison of the predicted dates of maxima and minima for 1921, which were published in H. C. 224, has been made with the observed values as here given. The average difference for 424 maxima common to both lists is ± 12.5 days. For 412 minima common to these lists the average difference is ± 15.0 days. Expressed in percentages, 33 per cent of the determinations are within 5 days of the predicted dates, 56 per cent are within 10 days, while 88 per cent differ less than 25 days. The average period is of the order of 310 days.

When we consider that these differences between observed and predicted phenomena involve the recognized irregularities in the variables as well as the uncertainty in some of the elements used, we are led to place considerable confidence in the annual predictions.

JULY 5, 1922.



HARVARD COLLEGE OBSERVATORY

CIRCULAR 236

THE VARIATIONS IN LIGHT AND COLOR OF Y SAGITTARII

BY HARLOW SHAPLEY AND ARVILLE D. WALKER

ON the basis of spectroscopic work at the Lick Observatory in 1908 and at the Mount Wilson Observatory in 1921, Professor Duncan has announced changes in the velocity curve of Y Sagittarii, 181518, that may be of considerable importance for theories of Cepheid variation. An abstract of his report to the American Astronomical Society has been published in *Popular Astronomy* for February, 1922. Using the customary double star notation to interpret the separate velocity curves for 1908 and 1921, he finds, in all the elements, changes that are larger than the computed probable errors.

The eccentricity shows the most conspicuous alteration, increasing from 0.21 ± 0.04 in 1908 to 0.42 ± 0.04 in 1921. The velocity of the center of mass changes from $+3.6 \pm 1.2$ km to -5.9 ± 1.5 km. The latter change might be attributed to the presence of an unknown companion; but the increase in eccentricity, which alters appreciably the shape of the velocity curve, appears to have no obvious explanation.

The similarity in the form of curves representing variations in light and velocity has been for many years well established for Cepheid variables, mainly through the spectroscopic work at the Lick Observatory. A change in the shape of the light curve should therefore be expected to follow any large modification in the eccentricity. With the aid of the Harvard collection of stellar photographs, it is possible to derive light curves for Y Sagittarii roughly coincident with Duncan's two spectroscopic investigations. We have, therefore, undertaken a study of the period and photographic variations, obtaining the results described below.

Three hundred and sixty-six photographs have been measured, covering the interval from 1901 to 1922. The comparison stars are given in Table I. The series of plates has been divided into three epochs as follows:

	Years	Observations
Early	1901 to 1909.5	99
Middle	1909.5 to 1917	160
Late	1917 to 1922	107

Hellerich's period, which was adopted by Duncan, is found unsatisfactory. Using only the Harvard photographic observations, we obtain a correction of $+0^d.00013$ to Hellerich's period, and adopt the following light elements:

$$\text{Max.} = \text{J.D. } 2420255.23 + 5^d.77340 \text{ E.}$$

The new value of the period agrees exactly with the one that was derived by Chandler in 1904 (A. J. 553) and verified nine years later by Lutzet's analysis of the visual observations, made by Yendell, Sawyer, and Lutzet, which extend over an interval of twenty-five years (Bul. Ast. 30, 15, 1913). The difference between the above value and the one used by Duncan is probably insufficient to explain the variation in the velocity curve.

TABLE I
COMPARISON STARS

Des.	B.D.	R.A. 1900	Dec. 1900	Pg.	Des.	B.D.	R.A. 1900	Dec. 1900	Pg.
Var.	$-18^\circ 4926$	$18^h 15^m .5$	$-18^\circ 54'$	..	d	$-18^\circ 4982$	$18^h 24.3^m$	$-18^\circ 47'$	6.54
b	$-18^\circ 4988$	25.6	$-18^\circ 28'$	5.15	g	$-19^\circ 4928$	9.4	$-19^\circ 1'$	6.76
c	$-20^\circ 5054$	9.3	$-20^\circ 46'$	5.20	h	$-18^\circ 4900$	12.9	$-18^\circ 12'$	7.36
a	$-20^\circ 5134$	19.4	$-20^\circ 35'$	6.05	k	$-17^\circ 5171$	17.2	$-17^\circ 43'$	7.53
e	$-18^\circ 4864$	9.7	$-18^\circ 42'$	6.11	l	$-18^\circ 4888$	12.0	$-18^\circ 51'$	8.00
f	$-18^\circ 4886$	11.6	$-18^\circ 30'$	6.49	m	$-18^\circ 4899$	12.9	$-18^\circ 19'$	8.92

Table II contains the observations grouped suitably for a comparison of the photographic light curves for different epochs. Corresponding to the phases in the second, third, and fourth columns, the mean magnitudes and the numbers of observations, in parentheses, are given in the next three columns for the early, middle, and late epochs, respectively.

In the eighth column are the differences in hundredths of a magnitude for early and late epochs. These two intervals cover the times of the Lick and Mount Wilson velocity curves. The ninth column contains the same magnitude differences after applying a constant zero-point correction of $+0.06$ to the magnitudes for the late epoch. This correction may indicate either that the variable is on the average six hundredths of a magnitude

brighter now than fifteen years ago, or that the mean of the comparison stars is now fainter. The last two columns contain the corresponding data for early and middle epochs, the zero-point correction being $+0.03$. In forming the magnitude differences the deviations in mean phase were ignored.

The corrected differences between the three light curves in Table II are hardly larger than the accidental errors affecting the work. Certainly there is no permanent photometric change comparable with the computed alteration in the eccentricity. A temporary deformation of the light curve, however, might easily escape detection. The mean magnitudes for the early and late epochs, the latter corrected as mentioned above, are plotted in the upper half of the figure. The circles represent values of lowest weight.

TABLE II
COMPARISON OF CURVES

Phase Limits	Mean Phases			Mean Magnitudes			Magnitude Differences			
	Early	Middle	Late	Early	Middle	Late	E-L	E-L'	E-M	E-M'
δ δ 0.2-0.6	0.498	0.366	0.345	6.08 (7)	5.99 (7)	6.17 (3)	- 9	-15	+ 9	+ 6
0.6-1.0	0.665	0.787	0.797	6.25 (4)	6.28 (10)	6.15 (5)	+10	+ 4	- 3	- 6
1.0-1.4	1.225	1.208	1.228	6.41 (6)	6.40 (13)	6.32 (12)	+ 9	+ 3	+ 1	- 2
1.4-1.8	1.645	1.579	1.521	6.58 (10)	6.51 (13)	6.46 (7)	+12	+ 6	+ 7	+ 4
1.8-2.2	1.916	1.981	2.033	6.58 (5)	6.57 (7)	6.59 (9)	- 1	- 7	+ 1	- 2
2.2-2.6	2.369	2.443	2.414	6.86 (7)	6.78 (18)	6.64 (9)	+22	+16	+ 8	+ 5
2.6-3.0	2.800	2.764	2.862	6.97 (8)	6.87 (14)	6.82 (5)	+15	+ 9	+10	+ 7
3.0-3.4	3.248	3.214	3.186	6.91 (8)	6.95 (12)	6.93 (8)	- 2	- 8	- 4	- 7
3.4-3.8	3.567	3.628	3.604	7.03 (7)	6.94 (11)	6.95 (7)	+ 8	+ 2	+ 9	+ 6
3.8-4.2	3.930	4.035	3.951	7.05 (6)	7.05 (13)	7.06 (4)	- 1	- 7	0	- 3
4.2-4.6	4.451	4.424	4.380	6.95 (7)	7.02 (13)	6.84 (6)	+11	+ 5	- 7	-10
4.6-5.0	4.799	4.821	4.782	6.82 (10)	6.80 (7)	6.73 (11)	+ 9	+ 3	+ 2	- 1
5.0-5.4	5.200	5.152	5.228	6.40 (7)	6.41 (10)	6.37 (8)	+ 3	- 3	- 1	- 4
5.4-5.6	5.470	5.522	5.516	6.10 (3)	6.00 (8)	5.90 (6)	+20	+14	+10	+ 7
5.6-0.2	5.717	5.772	5.724	5.86 (4)	5.84 (4)	5.97 (7)	-11	-17	+ 2	- 1

Luizet intercompared his mean visual curve of Y Sagittarii for the two intervals 1898-1904 and 1905-1912, and also found no difference in form.

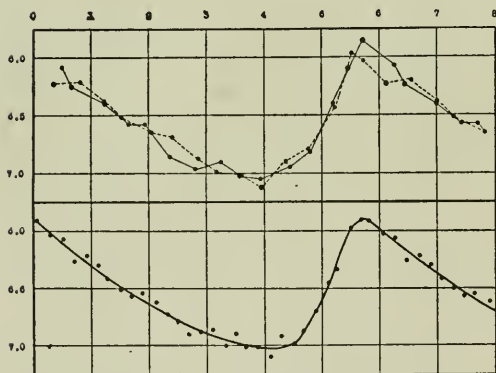
The mean photographic light curve for the whole interval 1901-1922 is given in Table III, and the residuals in hundredths of a magnitude indicate the deviation of the observed means from a smooth curve. The mean curve shown in the lower part of the accompanying figure is in all ways typical of the average Cepheid variable.

TABLE III
MEAN MAGNITUDES

Phase	Magnitude	O-C	Phase	Magnitude	O-C
d			d		
0.048	5.91 (5)	-1	3.100	6.86 (14)	-6
0.288	6.03 (7)	+2	3.331	7.00 (14)	+4
0.507	6.07 (10)	-4	3.509	6.90 (11)	-8
0.706	6.26 (14)	+7	3.678	7.02 (14)	+2
0.926	6.22 (5)	-5	3.884	7.01 (12)	-1
1.115	6.30 (13)	-5	4.112	7.10 (11)	+7
1.295	6.42 (18)	+1	4.299	6.92 (11)	-11
1.509	6.51 (17)	+3	4.511	6.99 (15)	0
1.689	6.57 (13)	+4	4.680	6.87 (13)	0
1.868	6.54 (11)	-4	4.900	6.70 (15)	+1
2.120	6.62 (10)	-4	5.116	6.45 (13)	-2
2.313	6.73 (14)	0	5.270	6.34 (12)	+4
2.495	6.78 (20)	0	5.510	5.98 (17)	0
2.694	6.90 (14)	+7	5.692	5.90 (10)	-1
2.899	6.88 (13)	0			

The magnitude, color, and spectral limits for Y Sagittarii are as follows:

	Pg. Mag.	Vis. Mag.	Color Index	Spectrum
Maximum.....	5.90	5.44	+0.46	F4
Minimum.....	7.03	6.18	+0.85	G4
Range.....	1.13	0.74	0.39	1.0



Light curves of Y Sagittarii. Ordinates are apparent visual magnitudes; abscissas are phases in days.

AUGUST 5, 1922

The visual magnitudes are taken from Professor E. C. Pickering's observations in H.A. 46, Part II, 1904. The limiting spectral classifications are by Shapley from Mount Wilson photographs (Mt. W. Contr. 124, 1916). The ranges in magnitude, color, and spectrum are of the amount usual for long period Cepheids, and the agreement of color with class of spectrum is good. One-third of the photographic range is due to change of color.



HARVARD COLLEGE OBSERVATORY

CIRCULAR 237

NOTES BEARING ON THE DISTANCES OF CLUSTERS

By HARLOW SHAPLEY

THE five items printed in this Circular, concerning variable stars of the Cepheid class, are collected under the above title because they all bear directly on the distances derived by the writer for globular clusters. The notes can be taken in part as an answer to various criticisms that lately have been made of these results.

I. THE VELOCITIES OF CLUSTER TYPE VARIABLE STARS

In a recent important paper, Kapteyn and van Rhijn have published data on proper motion for fourteen faint Cepheids of the so-called cluster type.¹ The average annual proper motion is $0''.07$, a high value for stars of the tenth apparent magnitude. The result, I believe, supports my earlier conclusion that the average space velocity of the cluster variables is very high;² but Kapteyn and van Rhijn do not interpret their results in this way. From the observed proper motions, they compute large parallaxes and relatively low luminosities for these short period Cepheids. They conclude, therefore, that the analogous short period Cepheids in clusters may also be dwarfs, and consequently that the distances I assign globular clusters may be about eight times too great. Apparently they have overlooked the significance of the extraordinary peculiar motions and some other relevant factors in this problem of stellar luminosity and galactic dimensions.

Since Kapteyn and van Rhijn's paper has been widely copied and commented upon, it may be well to refer again to what is known about the motions of cluster variables. At the same time we shall examine further the valuable addition they make to the observational data.

1. At the Lick Observatory in 1913, Kiess³ derived a mean radial velocity of -50 km for RR Lyrae. Hertzsprung⁴ found that the annual proper motion is about $0''.25$. Van Maanen⁵ has measured the proper motion and parallax of this variable, commenting on the high luminosity and uncommonly great velocity in space.

The annual proper motion of XZ Cygni,⁶ deduced by Tucker, is $0''.1$, and, according to Adams, the radial velocity has the extremely high value of -196 km. Adams also found the radial velocities of RS Bootis, SU Draconis, and SW Draconis near maximum to be -51 , -193 , and -74 km,⁷ and the work has since been extended at Mount Wilson to other faint variables of this class.⁸

Bailey and others have frequently noted that the variables in globular clusters are more widely distributed in space than other stars. This may be taken as further evidence of their intrinsically high velocities. Similarly, the wide distribution in latitude of cluster variables of the galactic system suggests unusual peculiar motions.

2. In view of the above direct and indirect evidence that the cluster variables as a class have high spatial velocity and, therefore, that the large proper motions are not incompatible with high luminosity, we may reasonably question the conclusion of Kapteyn and van Rhijn. They do not mention specifically, but probably recognize, that if these variables have distances one-eighth the values I give, and the clusters are correspondingly near at hand, then the numerous blue stars in the globular clusters would be four or five magnitudes fainter absolutely than the similar stars in the galactic system and in the Orion and Scorpio-Centaurus clusters as analyzed by Kapteyn; the same inequality would also apply to the long period Cepheids and the giant red stars. Notwithstanding this implicit assumption of a general incongruence between Galaxy and clusters, they accept the comparability of the cluster variables wherever found.⁹ (The preferable assumption of universal comparability for every type has so far encountered no serious inconsistency, even, as shown below, for these cluster variables of high peculiar velocity.)

3. Stars of Class R, according to Sanford,¹⁰ have extraordinarily high velocities, of much the same order as the velocities of the cluster variables; they are also widely distributed in galactic latitude and are probably giants. The long period variable stars of spectral class M are giant stars, have peculiarly high radial velocities, and are widely distributed in galactic latitude.

Apparently, then, neither high velocity, nor relatively large proper motion, nor wide galactic distribution, are invariable criteria of low luminosity or of small mass. According to Plaskett, Y Cygni, one of the most massive stars known, moves with a velocity of 49 km, an uncommonly high value for a star of spectral class B2.

4. It is generally recognized that the procedure involving parallactic motion, used by Kapteyn and van Rhijn to get the mean distances of cluster variables, is inappropriate for stars of high peculiar velocity. Russell has analyzed the prob-

lem recently, and finds that if the average radial velocity is more than 14 km the parallactic-motion method is less accurate than a method involving the peculiar motions directly.¹¹ For the Cepheids of long period which were used in estimating the distances of clusters, the average radial velocity is less than 10 km. For the cluster variables the average appears to be more than ten times as great, and it follows that, for a given number of such stars, the peculiar motions yield a mean parallax with fifty times the weight of one based on parallactic motion. And, of course, to make the peculiar motions of such speedy stars of much value in measuring a mean parallax, considerable material is required.

5. Notwithstanding the inapplicability of the method, the computations by Kapteyn and van Rhijn show what appears to be genuine parallactic motion. At first sight this would seem to support their conclusion that the cluster variables are not distant. Further investigation shows, however, that the computed systematic motion is probably not a reflection of the Sun's motion. Rather it appears to be a clue to an interesting and heretofore unknown property of these variable stars.

6. The apparent parallactic drift is shown, in the table published by Kapteyn and van Rhijn, by the circumstance that of the fourteen values of the v -component of proper motion (in the direction opposite to the solar apex), only four values are negative. The values of the τ -component, at right angles to the v -component, are not printed. I have re-computed them, and find, not an approximately random distribution, as should hold for a true parallactic drift, but a distinct southern streaming. There is as good evidence of systematic drift across the Sun's way as along it.

Further, the average value of the v -components (without removing from them the supposed parallactic drift) is $0''.048$; the average value of the τ -components is $0''.047$. By reducing the proper motion of the brightest and nearest star, RR Lyrae, to the mean distance of all fourteen, the above averages become $0''.038$ for v and $0''.041$ for τ ; omitting RR Lyrae, the averages are $0''.037$ and $0''.040$. The similarity of these averages appears to leave no room for a large parallactic drift due to the motion of the Sun toward the usually adopted apex.

The mean parallactic drift computed by Kapteyn and van Rhijn is $+0''.0258$. The parallactic drift according to the distances I give the cluster variables of the galactic system is $+0''.0035$, a value that conforms with the relatively negligible solar drift indicated by the comparability of the τ and v components.

7. Little as we know of the radial velocities, a much better result for the mean parallax of the cluster variables can now be derived from the peculiar motions than

from the parallactic drift. The mean radial velocity of the five stars named above is 113 km. By reducing this value to 100 km, allowance is made for the probable variation in velocity of the stars incompletely observed. When the individual proper motions are reduced to magnitude 10 and Kapteyn and van Rhijn are followed in weighting the photographic and meridian observations of positions, the mean τ is $0''.0031$. Hence the mean parallax is $0''.00147 \pm 0''.00039$, the probable error being computed by Russell's formulae.¹² This value, based on so little material, cannot be considered of high weight, but it has thirteen times the weight assigned by Kapteyn and van Rhijn to the mean parallax computed from the fourteen v -components. Moreover, this preliminary value from the peculiar motions is only 1.8 ± 0.5 times the parallax given by the period-luminosity curve for tenth magnitude stars. The corresponding absolute magnitude is $+0.8 \pm 0.6$, compared with my value -0.35 , and the value $+4.0$, computed from the parallaxes given by Kapteyn and van Rhijn.

8. Assuming random space velocity for the cluster variables and my values of the parallax, we compute from the observed proper motions that the average radial velocity should exceed 160 km. But the theoretical relations between radial velocity, transverse velocity, and space velocity probably do not hold for these stars because of the conspicuous streaming mentioned above; the relations fail for stars of high velocity in general, according to recent investigations by Adams, Joy, and Strömberg.¹³ It will therefore not be easy to determine a good mean parallax of cluster variables from a direct correlation of proper motion and radial velocity, even when we have a considerably greater amount of data.

9. Following up the indication that cluster variables are drifting systematically with a high velocity, part of which is reflected as an apparent parallactic motion, I have computed the coordinates of the apex of the drift (the anti-apex of solar motion with respect to these stars) from the proper motions given by Kapteyn and van Rhijn.

The results are as follows:

$$\text{R. A.} = 152^\circ$$

$$\text{Decl.} = -41^\circ$$

$$\text{Secular drift, } \mu_1 = +0''.043$$

$$\text{Gal. Long.} = 242^\circ$$

$$\text{Gal. Lat.} = +12^\circ$$

For this solution the proper motions were reduced to a common distance represented by the apparent visual magnitude, $m = 10$. Adopting $M = -0.35$ for the absolute visual magnitude, we have for the transverse velocity of the drift, in kilometers a second,

$$V_t = 4.74\mu_1 10^{0.2(m-M)+1} = 240$$

The motion of one of these stars, RZ Cephei, is very different from the others. Its transverse velocity is five times the average for the other thirteen (H.B. 773), and its proper motion has a large component, $+0''.179$, northward. The remaining group gives the following preferable values for the position of apex and stream velocity:

R. A. = $157^\circ \pm 15^\circ$	Gal. Long. = 253°
Dec. = $-57^\circ \pm 9^\circ$	Gal. Lat. = $+1^\circ$
$\mu_t = +0''.039 \pm 0''.008$	$V_t = 220$ km.

The position of the apex is in exact agreement with that found by Strömberg for all stars of high velocity.¹⁴ The radial velocities so far published conform qualitatively with the direction of the drift indicated by the proper motions.

If we accept the conclusion that, through the intermediary of long period Cepheids and globular clusters, the absolute magnitudes and distances of cluster variables can be determined with high accuracy, it appears that in this drift of variable stars there may be a means of analyzing the structure, direction, and speed of the general stream of high velocity stars. The careful determination for these variables of proper motions, apparent magnitudes, and radial velocities thus becomes of special importance.

II. LONG PERIOD CEPHEIDS IN GLOBULAR CLUSTERS

In the paper already mentioned, Kapteyn and van Rhijn state that seven or eight long period Cepheids are found in two globular clusters. The case for the common appearance of cluster variables and typical Cepheids is much stronger than this statement might indicate. It is shown in Mount Wilson Contribution 151 that five bright globular clusters contain long period Cepheids. Four of these clusters, Messier 3, 5, 15, and ω Centauri, contain also large numbers of cluster type variables, and the difference in magnitude between the two types is in all cases very close to the difference predicted by the adopted period-luminosity curve. The high galactic latitude of these clusters makes it impossible to believe that the typical Cepheids found within them are chance projections of galactic stars.

Cepheid variables of long period have also been found in N.G.C. 6779 and N.G.C. 6229.¹⁵ Probably some of the other bright variable stars in globular clusters, for which light curves are not yet available, are likewise typical Cepheid variables. It seems hardly reasonable to accept Kapteyn and van Rhijn's suggestion that the long period Cepheids in all these clusters are abnormally faint.

III. LIGHT CURVES OF MAGELLANIC CLOUD VARIABLES

In H.C. 173 Miss Leavitt states that the variable stars so far investigated in the Magellanic Clouds resemble the variables found in clusters, but no light curves or tables of observations have ever been published. In Figure 1 the light curves are given for two typical stars from the Small Magellanic Cloud. The Harvard

numbers of these variables are 1492 and 821. Their periods are 6.2926 and 127.0 days, and the ranges in photographic magnitude are 1.0 and 0.9.

To illustrate better the comparability of these typical Cepheids of the Magellanic Clouds with the similar variables of the galactic system, the light curves of two galactic Cepheids are drawn through the observations in Figure 1, instead of curves based on the plotted points. To adjust the curve of one variable

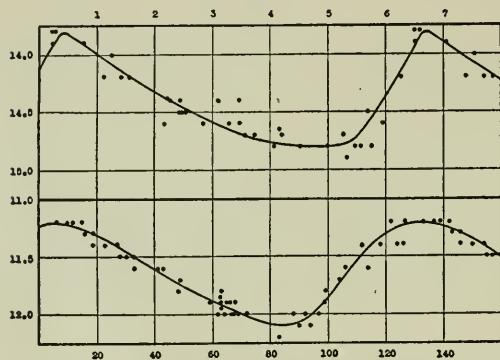


FIGURE 1.—Cepheid variables in the Small Magellanic Cloud. Ordinates are provisional photographic magnitudes; abscissas are phases in days.

to the range and period of another, linear transformations of the light intensities and phases are made with the aid of the relations

$$\Delta m_1 = -2.5 \log (1 - \Delta I_2 \Delta I'_1 / \Delta I'_2)$$

$$\Delta I = 1 - 10^{-0.4 \Delta m} \quad t_1 = t_2 P_1 / P_2$$

in which Δm and ΔI are the increments of magnitude and intensity measured from maximum, the subscripts denote the two variable stars, the prime refers to minimum light, and t and P are phase and period, respectively. The photographic light curve of the bright Cepheid, Y Sagittarii, period 5.77340 days, which is discussed in H.C. 236, is used for variable No. 1492 in the upper part of the figure. The photographic light curve recently derived by Jordan at Harvard for SX Herculis, period 102.8 days (H.B. 774), is used for the variable No. 821.

IV. INDIVIDUAL PERIOD-LUMINOSITY CURVES FOR ω CENTAURI AND THE SMALL MAGELLANIC CLOUD

The determination of the periods for some of the cluster variables in the Small Magellanic Cloud¹⁶ permits a direct comparison of the whole extent of the period-luminosity curve with the observations on period and magnitude. The twenty-five typical Cepheids, for which Miss Leavitt derived the periods, are represented by dots along the curve in the upper part of Figure 2. The thirteen cluster variables for which the logarithm of the period is less than zero, are represented by crosses in groups of five, four, and four, in order of decreasing period.

In the lower half of Figure 2, the data are plotted from Mount Wilson Contribution 151 for long period and short period Cepheids in the typical globular cluster ω Centauri. The three crosses on the right represent means for 19, 37, and 34 cluster variables, in order of decreasing period.

The exactness with which the previously adopted period-luminosity curve fits the observations in both of these cases appears to be conclusive evidence that the two kinds of Cepheids are regularly of comparable luminosity.

The high luminosity of long period Cepheids in the galactic system and in the Small Magellanic Cloud is commonly admitted. Kapteyn and van

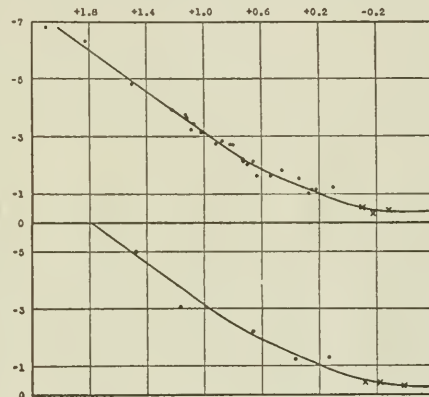


FIGURE 2.—The adopted period-luminosity curve, and observations for the Small Magellanic Cloud (above) and the globular cluster ω Centauri. Ordinates are absolute visual magnitudes; abscissas are logarithms of the period.

Rhijn have just shown¹⁷ that for seventeen galactic stars of this kind (for which they consider the motions well determined) the mean parallax, assuming a solar velocity of 19.5 km, is $0''.0029$. With the preferable solar velocity of 21.5 km, the mean parallax is $0''.0026$. From their data, I compute that the corresponding mean logarithm of the period is $+0.88$ and the absolute magnitude is -2.6 . The absolute magnitude from the period-luminosity curve for this value of log. period is -2.7 . The agreement is well within the uncertainties of the data, indicating that the zero point of the period luminosity curve cannot yet be revised on the basis of parallactic motion.

Taken in connection with the curves of Figure 2, this result shows that cluster variables cannot easily be assigned a mean absolute magnitude fainter than zero.

V. TRIGONOMETRIC AND SPECTROSCOPIC PARALLAXES OF CEPHEID VARIABLES

The numerical values of the distances derived by the writer for globular clusters depend directly or indirectly on the zero point of the period-luminosity curve, which in turn is fixed by the mean parallax of bright galactic Cepheids. Nearly all investigators, who have considered the distances of these stars, find them highly luminous. The absolute magnitude just computed from Kapteyn and van Rhijn's value of the mean parallactic motion is typical. Distances based on parallactic motion, however, may be subject to some uncertainty because of the possibility of unrecognized streaming. For instance, in the case of the short period Cepheids, as we have seen in Section I, the peculiar drift disqualifies the usual methods.

An important contribution to the problem has been made through recent work by observers of trigonometric parallax. The following table contains a comparative summary of the parallaxes of fourteen Cepheid variables.

PARALLAXES OF CEPHEID VARIABLES

Star	Mag.	Per. Lum.	Spec.	Trig.	p. e.	Observer	Trig. (Uncorrected)
α UMi	2.1	0.016	0.010	+0.028	± 0.018	Flint et al	+0.028
SU Cas	5.9	0.004	0.003	+0.008	0.004	Mt. Wilson	+0.010
RX Aur	7.6	0.001	0.001	-0.001	0.005	Mt. Wilson	+0.001
T Mon	6.2	0.001	0.003	-0.011	0.008	McCormick	-0.009
RT Aur	5.3	0.004	0.003	+0.008	0.004	Remark 1	+0.012
ζ Gem	4.0	0.004	0.003	+0.007	0.003	Remark 2	+0.010
RR Lyr	7.2	0.003	0.004	+0.006	0.006	Mt. Wilson	+0.008
U Vul	7.0	0.001	0.002	-0.003	0.009	McCormick	-0.001
η Aql	4.0	0.005	0.004	0.000	0.011	McCormick	+0.002
S Sge	5.8	0.002	0.002	+0.001	0.007	McCormick	+0.003
X Cyg	6.5	0.001	0.002	-0.009	0.009	Sproul	+0.003
T Vul	5.8	0.003	0.003	+0.016	0.008	McCormick	+0.018
β Cep	3.3	0.018	....	-0.009	0.009	Yerkes	-0.013
δ Cep	4.1	0.005	0.004	+0.013	0.009	Allegheny	+0.009

Remark 1. Mt. Wilson, Sproul, McCormick.

Remark 2. Allegheny, Sproul, Abetti, McCormick.

The median visual magnitudes and the parallaxes based on the period-luminosity curve are given in the second and third columns.¹⁸ The spectroscopic parallaxes in the fourth column are taken from the Mount Wilson catalogue.¹⁹ The relative trigonometric parallaxes and the probable errors were kindly supplied by Professor Schlesinger and Professor Mitchell. From these relative parallaxes,

absolute values have been computed and are given in the last column. The systematic corrections derived by van Maanen and Miss Wolfe²⁰ were used to obtain the corrected absolute trigonometric parallaxes in the fifth column. Similar systematic corrections were derived independently by Strömberg.²¹ The probable errors and the sources of the trigonometric parallax appear in the sixth and seventh columns.

The individual parallaxes from the period-luminosity curve and from Mount Wilson spectra are nearly identical for all stars except Polaris. The mean parallax from the period-luminosity curve is $0''.0049 \pm 0''.0009$; the mean trigonometric parallax is $+0''.0039 \pm 0''.0020$. The first is based on parallactic motion and peculiar velocities; the second is quite independent of such data. The mean of the trigonometric parallaxes uncorrected for systematic error is $+0''.0058 \pm 0''.0018$.

The difference between the parallax from the period-luminosity curve and the corrected trigonometric parallax is less than the probable error of the latter for seven stars in the above list, is equal to the probable error for three stars, and is greater for four stars.

After reducing the trigonometric parallaxes to the distances corresponding to apparent magnitude 5, the mean absolute magnitude, $\bar{M} = 10 + 5 \log \bar{\pi}$, for these fourteen Cepheid variables is found to be -3.3 ± 2.3 (or -1.1 ± 0.7 for the uncorrected parallaxes). Since the mean logarithm of the period for the same stars is 0.66, the corresponding absolute magnitude from the period-luminosity curve is -2.0 . The trigonometric parallaxes, therefore, support the results from proper motion and the related conclusions concerning the distances of clusters; they are insufficient as yet for a revision of the zero point of the period-luminosity curve.

SUMMARY AND CONCLUSIONS

1. An analysis of the data on proper motion for cluster variables fails to support the objections raised by Kapteyn and van Rhijn to the distances estimated by the writer for globular clusters.

2. The cluster variables of the galactic system appear to have such abnormally high velocities in space that the method of computing mean distances, used by Kapteyn and van Rhijn, is of low weight. The high velocities apparently produce the large proper motions and the wide distribution in galactic latitude.

3. The variables of this kind so far investigated seem to be affiliated with the stream of high velocity stars found by Adams, Joy, and Strömberg at

Mount Wilson. The space velocity of the drift exceeds 200 kilometers a second, and there is considerable dispersion in velocity.

4. The drift is parallel to the Milky Way, and its apex is in Vela or Carina, in the general direction of the center of the local system.

5. The average velocity of globular clusters is comparable with that of cluster variables in the galactic system. This may indicate that many of the cluster variables of the Galaxy were originally members of the same extragalactic cluster or cloud. It is possible that the high velocity and the variability of these stars both arise from close encounters with bodies of excessive mass, which would occur more frequently in the centers of globular clusters than anywhere else in the stellar system. We might thus account for the relative infrequency of cluster variables in the Magellanic Clouds and also for the reappearance of Cepheid variation among the blue stars.

6. The cluster variable RZ Cephei, with a velocity in excess of 1000 kilometers a second, appears to have the fastest motion yet recorded for a star.

7. The average absolute magnitude previously assigned to cluster variables in the galactic system and in the globular clusters is not inconsistent with the new data on proper motion.

8. Cluster variables and long period Cepheids are associated in at least six different globular clusters and in the Small Magellanic Cloud.

9. Light curves of the long period Cepheids in the Small Magellanic Cloud are shown to be comparable with the light curves of galactic Cepheids of similar period (Figure 1.)

10. Individual period-luminosity curves for ω Centauri and the Small Magellanic Cloud, Figure 2, show that the cluster variables are brighter than absolute magnitude zero, if the high luminosity of typical long period Cepheids is accepted. These individual curves are identical with the period-luminosity curves previously adopted from all available data.

11. A new determination of the zero point of the period-luminosity curve has been derived from the mean parallax computed by Kapteyn and van Rhijn for seventeen long period Cepheid variables. The new value agrees essentially with the former value based on eleven stars. The mean absolute visual magnitude of the seventeen stars is -2.6 .

12. The Mount Wilson spectroscopic parallaxes of Cepheid variables are in nearly exact agreement, star for star, with the parallaxes based on the period-luminosity curve. In the mean these two kinds of parallax should agree qualitatively, because the zero points for both methods are based on the proper motions of stars of similar spectral characteristics.

13. The trigonometric parallaxes, though affected by accidental errors relatively large compared with the parallaxes themselves, on the average agree within the probable errors with the parallaxes derived from the period-luminosity curve. The average trigonometric parallax is slightly smaller than the period-luminosity parallax, when the former is corrected for systematic errors, and is slightly larger when uncorrected.

1. *B. A. N.* No. 8, 1922.
2. *Mt. W. Contr.* 153, 10, 16, 1917.
3. *L. O. B.* 7, 140, 1913.
4. *A. N.* 196, 208, 1913.
5. *Mt. W. Contr.* 204, 4, 1920.
6. *Mt. W. Contr.* 153, 10, 1917.
7. *Ibid.*, and *Mt. W. An. Rep.*, 1918, p. 209.
8. *Mt. W. An. Rep.*, 1921, p. 268.
9. *Loc. cit.*
10. *Mt. W. An. Rep.* 1921, p. 269.
11. *Ap. J.* 54, 140, 1921.
12. *Ibid.*
13. *Mt. W. Contr.* 210, 1921.
14. *Mt. W. An. Rep.* 1921, p. 273.
15. *Pub. A. S. P.* 29, 210, 260, 1917.
16. *H. B.* 765, 1922; *Proc. N. A. S.* 8, 69, 1922.
17. *Loc. cit.*, p. 42.
18. *Mt. W. Contr.* 153, 1917.
19. *Mt. W. Contr.* 199, 1920.
20. *Mt. W. Contr.* 189, 1920.
21. *Mt. W. Contr.* 220, 1921.

AUGUST 25, 1922

HARVARD COLLEGE OBSERVATORY

CIRCULAR 238

LIGHT CURVE AND ORBIT OF A NEW ECLIPSING BINARY, H. V. 3622

BY IDA E. WOODS AND MARTHA B. SHAPLEY

The discovery of Harvard Variable No. 3622, from plates made at Arequipa, was announced in Harvard Bulletin 774. The star is an eclipsing binary of magnitude 9.7 at maximum, with a range of nearly three magnitudes. The spectral class is A2n, and the spectroscopic parallax from Harvard photographs is 0".0026. The heliocentric elements of light variation are:

$$\text{Min.} = \text{J. D. } 2412592.7905 + 8^d.01964 E$$

Ninety plates made with various instruments have been measured, and on 840 others the variable was found to be at maximum brightness. The photographic magnitude sequence for the comparison stars is given in Table I. The magnitudes are on the basis of the new international standards of 1922. The observations that show the star in or near the principal minimum, forty-

TABLE I
COMPARISON STARS

Desig.	C. DM.	R. A. (1900)	Dec. (1900)	Mag.	Spec.	Desig.	C. DM.	R. A. (1900)	Dec. (1900)	Mag.	Spec.
	^o	^h ^m	^o [']					^h ^m	^o [']		
Var.	-36 13430	19 7.6	-36 25	...	A2	m	...	19 7.0	-36 33	12.1	..
a	-37 13116	19 8.9	-37 8	7.0	A3	n	...	19 7.4	-36 27	12.3	..
b	-36 13459	19 10.3	-36 14	8.7	B9	o	...	19 8.1	-36 17	12.3	..
c	-36 13403	19 6.0	-36 20	8.9	A2	p	...	19 7.8	-36 24	12.4	..
d	-36 13438	19 8.3	-36 32	9.3	A3	q	...	19 6.9	-36 22	12.8	..
e	-36 13435	19 8.0	-36 25	9.9	A2	r	...	19 7.9	-36 29	12.9	..
f	-36 13423	19 7.1	-36 27	10.5	K2	s	...	19 7.8	-36 27	13.3	..
g	-36 13421	19 7.0	-36 37	11.0	K2	t	...	19 8.1	-36 19	13.6	..
h	-36 13431	19 7.8	-36 38	11.3	..	u	...	19 7.4	-36 27	14.2	..
k	-36 13426	19 7.1	-36 14	11.7	..	w	...	19 7.7	-36 23	14.4	..
l	-36 13414	19 6.5	-36 32	11.9	..						

five in number, are given individually in Table II. One plate was taken with the Bruce 24-inch Telescope, the others with the 1-inch Cooke or the 8-inch Bache.

TABLE II
PHOTOGRAPHIC OBSERVATIONS DURING MINIMUM

J.D. and G.H.M.T	Exposure	Phase	Mag.	O—C	J.D. and G.H.M.T.	Exposure	Phase	Mag.	O—C
	<i>m</i>	<i>d</i>				<i>m</i>	<i>d</i>		
2412592.886	10	+0.096	12.3	+0.10	2418190.617	12	+0.118	11.4:	-0.32:
2592.893	10	+0.103	12.1	+0.05	8406.867	10	-0.162	11.0	+0.08
2592.901	10	+0.111	12.0	+0.11	8823.875	60	-0.176	10.9	+0.17
3378.629	10	-0.087	11.9:	-0.46:	8831.828	120	-0.242	9.9	-0.15
3715.699	70	+0.159	11.0	+0.04	9561.727	62	-0.131	11.8	+0.37
4140.524	13	-0.057	12.4	-0.12	9593.716	60	-0.220	10.4	+0.17
4942.555	11	+0.010	12.7	+0.18	9601.647	60	-0.309	9.9	+0.14
5527.820	60	-0.159	10.7:	-0.24:	2420363.614	65	-0.208	10.4	+0.04
5960.751	60	-0.288	9.8	-0.01	0668.768	60	+0.200	10.4	-0.03
6257.776	60	+0.010	12.7	+0.18	0708.728	60	+0.062	12.4	-0.12
6289.767	60	-0.078	12.4	-0.10	0724.654	61	-0.052	12.4	-0.12
6289.810	60	-0.035	12.5	-0.02	0748.566	62	-0.198	10.4	-0.05
6297.698	66	-0.166	10.8	-0.04	0748.611	60	-0.153	11.0	-0.02
6337.708	60	-0.254	10.0	+0.03	0756.574	60	-0.210	10.4	+0.05
6634.721	10	+0.032	12.4:	-0.12:	1045.752	10	+0.261	10.0	+0.05
6682.584	62	-0.223	10.2	0.00	1069.654	10	+0.104	12.0:	-0.01:
6698.632	71	-0.214	10.3	+0.02	1157.512	30	-0.254	9.9	-0.09
6979.777	60	+0.243	10.1	+0.04	1309.880	30	-0.259	9.8	-0.14
7019.778	68	+0.146	11.2	+0.04	1430.685	30	+0.251	10.0	0.00
7019.869	67	+0.237	10.1	0.00	1839.591	60	+0.156	10.8:	-0.19:
7051.745	48	+0.035	12.6:	+0.08:	2224.545	63	+0.167	10.8	-0.01
7075.657	61	-0.112	11.7	-0.14	2224.591	64	+0.213	10.4	+0.11
7805.658	60	+0.102	11.8	-0.26					

From this material two solutions for the orbit have been made, one on the assumption of stellar disks uniformly bright, and one assuming the disks completely darkened at the edge. The orbital elements, together with other information concerning the system, appear in Table III.

The observations during maximum light give no evidence of a measurable secondary minimum—an expected result, since the computed range in photographic magnitude does not exceed 0.03.

TABLE III
ORBITAL ELEMENTS AND OTHER DATA

Right Ascension, 1900.....	19 ^h 7 ^m .6	
Declination, 1900.....	−36° 25′	
Galactic Latitude.....	−21°	
Galactic Longitude.....	329°	
Period.....	8 ^d .01964	
Nature of eclipse.....	Total	
Photographic magnitude at maximum.....	9.68	
Photographic magnitude at minimum.....	12.52	
Observed range at primary minimum (pg. mag.).....	2.84	
Photographic light of brighter star.....	0.927	
Photographic light of fainter star.....	0.073	
Inclination of orbit.....	Uniform 84° 6′	Darkened 87° 30′
Least distance of centers projected.....	0.103	0.044
Semiduration of primary eclipse.....	0 ^d .332	0 ^d .356
Semiduration of totality.....	0 ^d .074	0 ^d .069
Computed range at secondary minimum (pg. mag.).....	0.012	0.03
Radius of brighter star.....	0.078	0.104
Radius of fainter star.....	0.196	0.174
Most probable density of brighter star.....	0.22	0.09
Most probable density of fainter star.....	0.01	0.02
Radius of brighter star in terms of Sun's radius....	1.7	2.2
Radius of fainter star in terms of Sun's radius.....	4.2	3.7
Distance of centers in terms of Sun's radius.....	21.2	21.2
Ratio of surface brightness.....	80	35
Photographic absolute magnitude of brighter star... +1.3		+0.7
Photographic absolute magnitude of fainter star... +4.0		+3.4
Hypothetical parallax.....	0 ^o .002	0 ^o .0015
Spectroscopic absolute magnitude of brighter star (visual).....	+1.8	

The representation of the observations during minimum by the curve computed for uniformly luminous disks is shown in Figure 1. Uncertain measures are indicated by colons in Table II and by open circles in Figure 1.

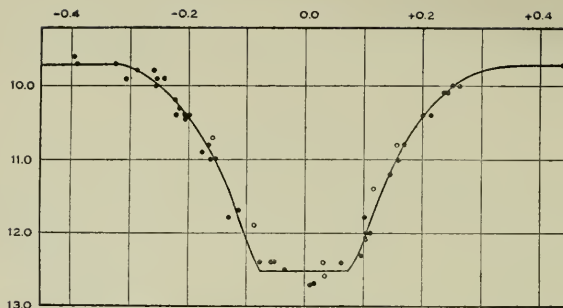


FIGURE 1.—Light curve of H.V. 3622. Ordinates are photographic magnitudes. Abscissas are phases in days.

The diagram in Figure 2 probably represents the system closely. It is based on an interpolated set of orbital elements, in which the cosine of the inclination and the relative radii of the two stars are means of the corresponding values for the limiting orbits given in Table III.

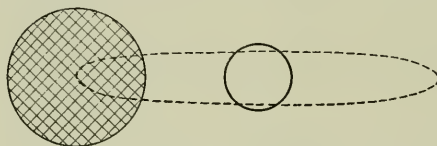


FIGURE 2.—Diagram of the eclipsing system H. V. 3622 at greatest elongation.

SEPTEMBER 28, 1922



HARVARD COLLEGE OBSERVATORY

CIRCULAR 239

THE DISTRIBUTION OF STARS OF SPECTRAL CLASS

BY HARLOW SHAPLEY AND ANNIE J. CANNON

THE distribution of the stars of spectral classes B0 to B5 has been discussed in different ways by E. C. Pickering, H. C. Plummer, Kapteyn, Charlier, Shapley, and others, largely on the basis of the brighter stars. In the earlier discussions it was thought that few if any B stars existed fainter than the seventh apparent magnitude. It has since been shown that this is not the case; the distribution of the brighter B stars in a local system is responsible for the earlier deduction that faint stars of this class are uncommon.¹ It now appears that the fainter B stars are confined closely to a narrow belt along the galactic circle,² the brighter stars alone indicating the existence of the local star cloud which is not coincident with the general Galaxy.

In Harvard Circular 229, we have shown that the brighter stars of Class A (B8 to A3, inclusive) also show a trace of the local system. In the present discussion, which is based on the Henry Draper Catalogue, the dependence of the distribution of B stars on apparent magnitude is illustrated. In the four figures, points represent the individual stars and large open circles represent the median positions described below. Aitoff's equal area projection of the sphere is used for the system of galactic coordinates (H. A. 56). The figures are arranged in order of successively fainter magnitude limits.

No stars fainter than visual magnitude 8.25 are included in this discussion. The catalogue is selectively incomplete for fainter stars; also among these faint early B stars there is likely to be a systematic error of classification, when the dispersion is short, because of the absence of the finer lines of helium and other elements. On the basis of his work with slit spectrographs at Mount Wilson, Dr. Hubble suggests in a letter that a systematic error begins in the neighborhood of the seventh magnitude for nebulous stars of this spectral class. The deviation is in the sense of early B stars being frequently classed as late B stars; it is, therefore, of no serious consequence in the present discussion, but it might lead to

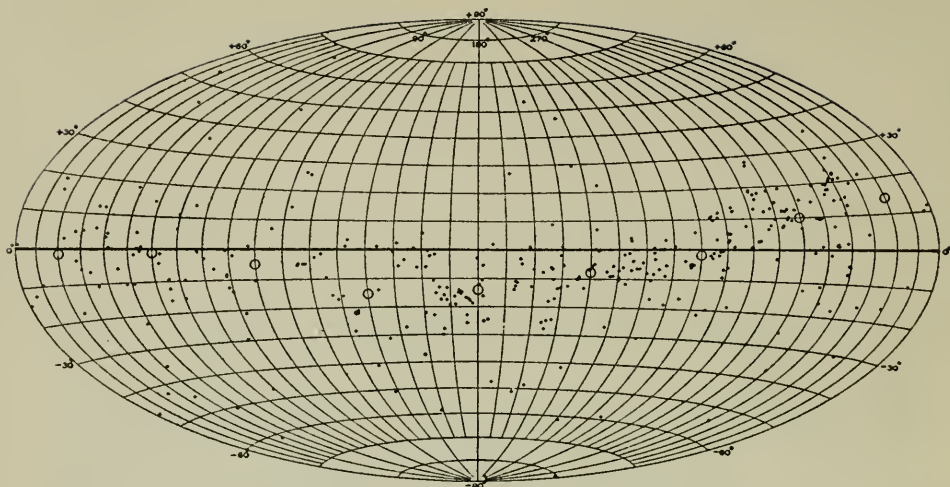


FIGURE 1.—Galactic distribution of stars of spectral Class B, brighter than magnitude 5.26.

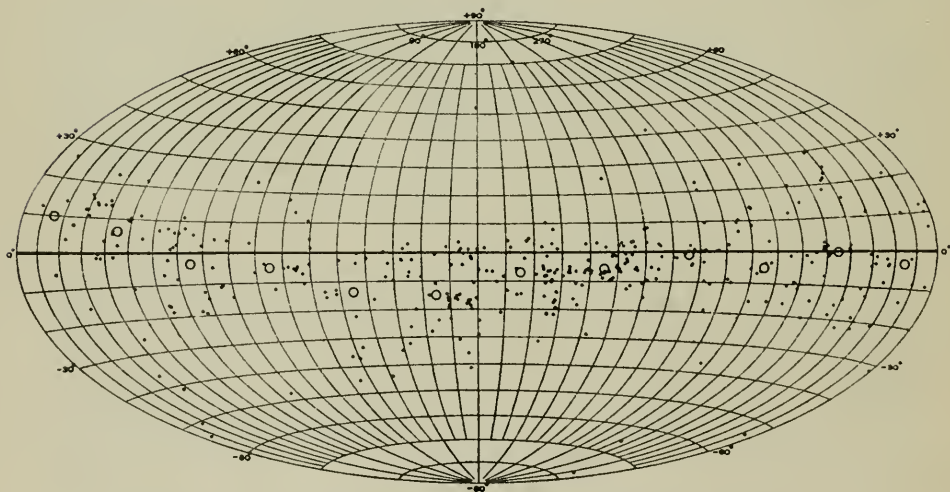


FIGURE 2.—Galactic distribution of stars of spectral Class B, magnitudes 5.26 to 6.25.

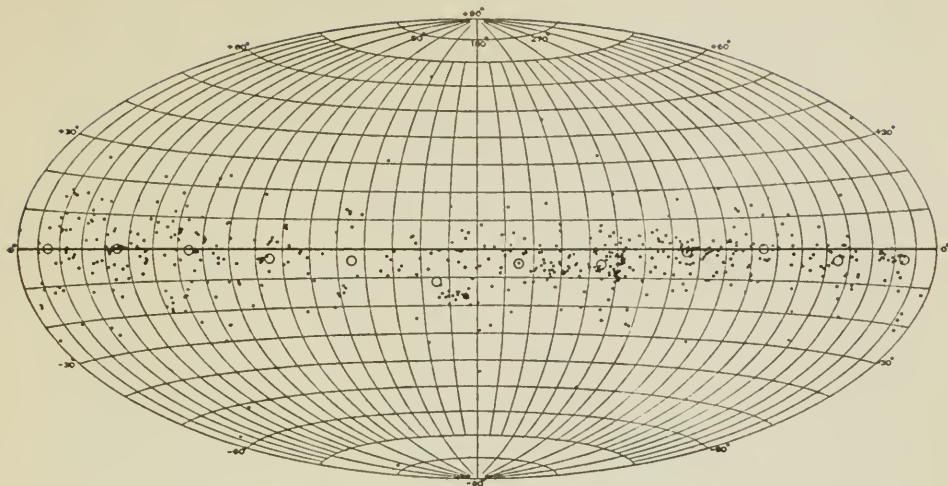


FIGURE 3. — Galactic distribution of stars of spectral Class B, magnitudes 6.26 to 7.25.

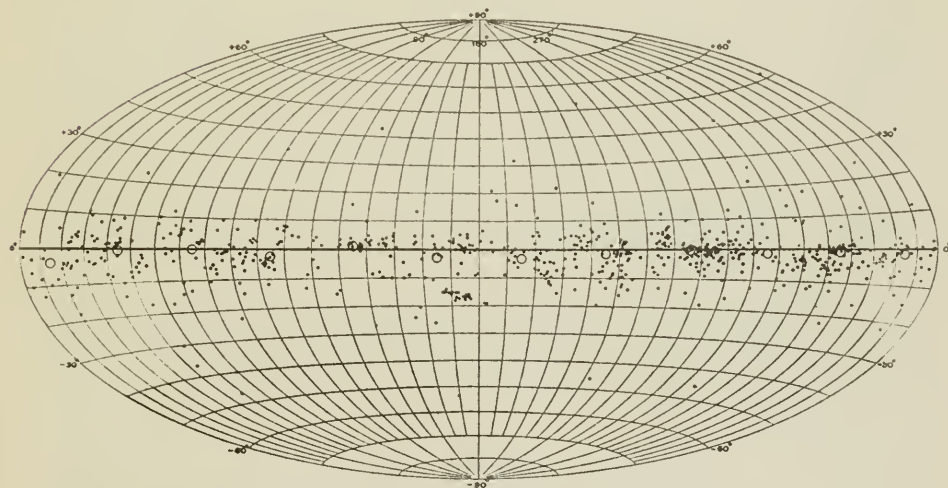


FIGURE 4. — Galactic distribution of stars of spectral Class B, magnitudes 7.26 to 8.25.

erroneous conclusions in a study of faint stars of Classes B8 and B9 because of the inclusion of earlier stars.

A description of the four figures, and a statement of the conclusions derived from a study of them, are summarized in the following paragraphs.

1. The positions of 346 stars brighter than visual magnitude 5.26 are shown in Figure 1, the central horizontal line being the galactic equator. The number of stars in successive intervals of 40° of galactic longitude, and the median galactic latitude for the stars in each interval, are as follows:

Longitude	20°	60°	100°	140°	180°	220°	260°	300°	340°
Number	24	31	22	28	50	55	53	65	18
Median Latitude	$-2^\circ.0$	$-1^\circ.5$	$-5^\circ.0$	$-15^\circ.5$	$-14^\circ.0$	$-7^\circ.0$	$-1^\circ.5$	$+10^\circ.5$	$+14^\circ.5$

Thirteen of these stars, or four per cent, are in higher galactic latitudes than 50° .

The distribution of these brighter stars, as well as those of fainter magnitudes, is conspicuously non-uniform in galactic longitude. This illustrates the greater richness of the southern sky in B stars, and is in marked contrast to the distribution of the brighter stars of Class A, discussed in Harvard Circular 229.

2. For the 367 stars in the magnitude interval 5.26 to 6.25, Figure 2 shows the distribution, and the following tabulation gives the number of stars and median latitude for each interval of 30° in longitude:

Longitude	15°	45°	75°	105°	135°	165°	195°	225°	255°	285°	315°	345°
Number	12	27	28	18	21	48	45	57	29	27	34	21
Median Latitude	$+10^\circ.0$	$+6^\circ.5$	$-3^\circ.5$	$-5^\circ.0$	$-13^\circ.5$	$-15^\circ.0$	$-7^\circ.5$	$-5^\circ.5$	$-0^\circ.5$	$-5^\circ.0$	$0^\circ.0$	$-3^\circ.5$

Seven of these stars, or two per cent, are in higher galactic latitude than 50° .

For this interval of magnitude, the preference for the local system is less pronounced than for the brighter stars. The relative infrequency in longitude 315° , latitude $+15^\circ$, probably indicates the obstructing action of the dark nebulosities in Ophiuchus and Scorpio.

3. Figure 3 shows the distribution in the magnitude interval 6.26 to 7.25. Probably about two-thirds of these 564 stars belong to the local system. Four of them, or one per cent, have higher galactic latitudes than 50° . The number and median galactic latitude, for successive intervals of 30° in galactic longitude, are as follows:

Longitude	15°	45°	75°	105°	135°	165°	195°	225°	255°	285°	315°	345°
Number	38	54	60	30	21	48	55	89	64	44	36	25
Median Latitude	$-0^\circ.5$	$0^\circ.0$	$-0^\circ.5$	$-3^\circ.5$	$-4^\circ.0$	$-11^\circ.5$	$-5^\circ.0$	$-5^\circ.0$	$-0^\circ.5$	$0^\circ.0$	$-3^\circ.5$	$-3^\circ.0$

The center of the local system is commonly thought to be in the general direction of galactic longitude 240° . There is a noticeably wider dispersion in latitude for these B stars in the direction opposite the center.

CLASS B STARS WITHIN 40° OF THE POLES OF THE GALAXY

H. D.	DM.	R.A. 1900		Dec. 1900		Vis. Mag.	Sp.	Gal. Long.	Gal. Lat.
		<i>h</i>	<i>m</i>	<i>o</i>	<i>s</i>			<i>o</i>	<i>s</i>
955	25	0	8.8	-18	6	7.25	B5	53	-78.5
5737	297	0	53.8	-29	54	4.39	B5	215	-87.0
10144	334	1	34.0	-57	44	0.60	B5	256	-59.0
15371	637	2	23.3	-48	9	4.44	B5	232	-61.5
16582	406	2	34.4	-0	6	4.04	B2	138	-51.0
17081	519	2	39.4	-14	17	4.39	B5	159	-58.0
20340	631	3	11.2	-17	12	7.82	B3	169	-53.5
23227	1430	3	38.3	-32	15	4.93	B5	197	-51.0
87015	2164	9	57.2	+22	26	5.59	B3	179	+52.5
91316	2166	10	27.5	+9	49	3.85	B0p	204	+54.5
93521	2179	10	42.7	+38	6	6.89	B3	149	+63.5
97991	3312	11	11.1	-2	55	7.28	B3	231	+52.5
100600	2374	11	29.5	+17	21	5.76	B3	212	+70.5
120086	2858	13	42.2	-1	58	7.7	B5	298	+57.5
120315	2027	13	43.6	+49	49	1.91	B3	63	+66.0
137569	2862	15	21.7	+15	3	7.9	B5	352	+51.0
138749	2750	15	28.9	+31	42	4.17	B5	18	+53.5
.....	15757	21	58.9	-27	19	5.84	B5	353	-53.5
.....	14063	22	1.9	-47	27	2.16	B5	319	-54.0
.....	6227	22	3.5	-19	1	5.74	B3	6	-54.0
.....	6196	22	5.2	-12	4	5.40	B5	17	-51.0
.....	6554	22	30.7	-16	54	6.69	B2	15	-57.5
.....	4818	22	58.8	+3	17	4.58	B5p	48	-50.5
.....	4985	23	8.9	+4	27	6.93	B2	53	-51.5
.....	6160	23	12.7	-9	44	4.56	B5	39	-61.5
.....	14047	23	41.9	-50	47	5.37	B5	292	-65.5
.....	17723	23	50.1	-32	29	6.05	B3	336	-77.5
.....	19790	23	5.72	-30	16	4.99	B5	345	-80.0

4. The 719 stars in the magnitude interval 7.26 to 8.25 are plotted in Figure 4. The four small open circles each indicate the mean position of five stars too close together to be plotted separately. Large open circles, as in the preceding figures, represent median galactic latitudes. The numbers and median galactic latitudes are as follows:

Longitude	15°	45°	75°	105°	135°	165°	195°	225°	255°	285°	315°	345°
Number	32	46	44	46	44	65	50	79	116	64	87	46
Median Latitude	-3°.5	-0°.5	0°.0	-2°.5	+1°.5	-2°.5	-3°.5	-1°.5	-0°.5	-1°.5	-1°.0	-1°.5

Four of these stars, or one-half of one per cent, have galactic latitudes in excess of 50° .

5. The average of the median galactic latitudes in Figure 4 is -1.4° , which may be taken as the dip of the galactic circle for stars at the distance here concerned. Assuming for them an average apparent magnitude of 7.9 and a mean absolute magnitude of -1.0 , we compute that the distance of the Sun to the north of the galactic plane is fifteen parsecs. This is only one-fourth the value indicated provisionally by the known Cepheid variables of long period.³

6. The group of twenty faint stars in the vicinity of longitude 172° , latitude -16° , in Figure 4 is in the constellation of Orion. As these are most probably members of the Orion cluster, we conclude that either their apparent magnitudes are faint because of obstruction by the nebulosities abounding in that region, or their absolute magnitudes are not normal. If the latter is the case, Kapteyn's value of the distance of the stars in Orion indicates that the absolute magnitudes of these twenty stars lie between $+1$ and $+2$. The Henry Draper Catalogue contains only four B stars fainter than apparent magnitude 8.25 in this same region.

7. The distance of the dark nebulosities in the Scorpio-Ophiuchus region may be estimated as between two hundred and three hundred parsecs.

8. All known B stars, to the apparent magnitude 8.25, in higher galactic latitude than 50° , are listed in the accompanying table. The classifications have been verified, but the spectra of the faintest stars in this list should be further studied.

9. The high concentration in low galactic latitude of the fainter B stars is illustrated in Figure 4 by the fact that more than ninety per cent are within ten degrees of the galactic equator.

1. *Mt. W. Contr.* 161, p. 29, 1918.

2. *Mt. W. Commun.* 64, 1919.

3. *Mt. W. Contr.* 157, p. 23, 1918.

HARVARD COLLEGE OBSERVATORY

CIRCULAR 240

ON THE SPECTRAL CONSTITUTION OF THE NEARER PARTS OF THE MILKY WAY

By HARLOW SHAPLEY

The distribution of eleven thousand stars along the Milky Way is discussed below on the basis of spectral class. In the tables and figures it is shown to what extent the arrangement of the stars down to the visual magnitude 8.25 depends on the galactic longitude. The star clouds of Cygnus and Carina, and the absorbing nebulosities in the vicinity of Taurus, apparently are important factors in distribution for certain classes of spectrum.

Since detailed statistical discussions of all stars in the Henry Draper Catalogue will be made at other observatories, only the stars in representative selected fields, in galactic latitudes 0° , $+10^\circ$, and -10° , are included in this treatment. Some of the results mentioned below have already been foreshadowed by the work of Nort, Dyson and Melotte, Pannekoek, and others, who have worked generally without reference to spectral class. A subsequent Circular will contain a comparison of the fields along the Milky Way with the non-galactic regions.

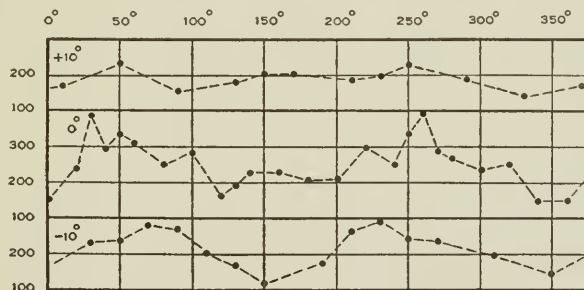


FIGURE 1.—Distribution of stars of all spectral classes combined for three different belts of galactic latitude. Ordinates for each section of the figure are the number of stars to magnitude 8.25 in 100 square degrees. Abscissas are galactic longitudes.

The centers and boundaries of the fields selected for the study of star distribution are given in Table I. The coordinates of each star have not been changed from the equatorial to the galactic system. Instead, counts have been made

between such computed limits of right ascension and declination that the center of gravity of each chosen area has the desired galactic coordinates, and each area contains one hundred square degrees.

Table II contains the final results in summarized form, the tabulated numbers representing all the stars of a given spectrum and magnitude interval in the fields of one hundred square degrees. The spectral classes contain subdivisions as adopted in Harvard Circular 226. The total numbers of stars to magnitude 8.25,

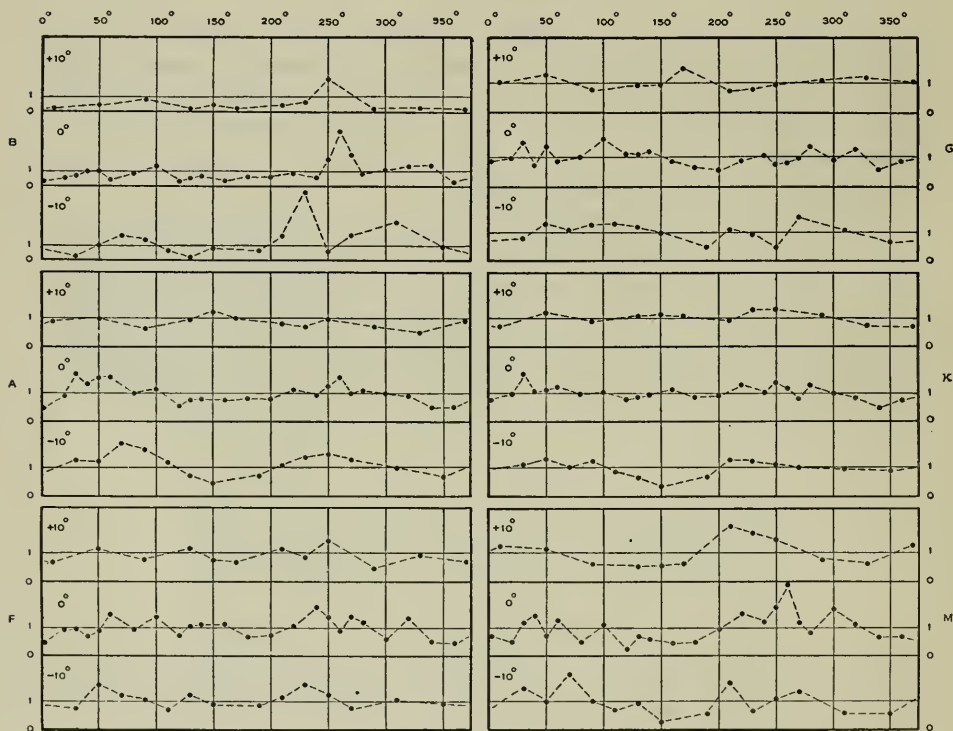


FIGURE 2.—Distribution along the Milky Way, in galactic latitudes $+10^\circ$, 0° , -10° , for various spectral classes, of stars with magnitudes between 7.00 and 8.25. Ordinates for each curve are ratios of the number of stars in a given longitude (abscissas) to the average for all longitudes.

given in the last column of Table II, are plotted against galactic longitude in Figure 1 for the three different belts of galactic latitude.

Figure 2 represents the data of the third section of Table II; that is, it shows, for each spectral class and latitude belt separately, the number of stars between

TABLE I
SELECTED FIELDS ALONG THE MILKY WAY

Longitude	Limits of R. A.				Limits of Dec.				Longitude	Limits of R. A.				Limits of Dec.			
Lat. $\pm 0^\circ$	h	m	h	m	°	'	°	'	Lat. $\pm 10^\circ$	h	m	h	m	°	'	°	'
0	18	20.0	to 18	59.9	- 4	59	to + 4	59	50	19	20.1	to 20	20.7	+43	40	to +53	39
20	18	58.0	19	40.0	+12	40	+22	39	90	23	32.8	1	47.2	+67	40	+77	39
30	19	18.3	20	3.1	+21	19	+31	18	130	4	59.3	5	59.9	+43	40	+53	39
40	19	41.6	20	30.3	+29	50	+39	49	150	5	55.9	6	42.7	+26	14	+36	13
50	20	9.6	21	4.2	+37	46	+47	45	170	6	36.6	7	17.8	+ 8	33	+18	32
60	20	45.0	21	47.0	+45	10	+55	09	210	7	55.7	8	38.5	-25	46	-15	47
80	22	37.2	23	58.7	+55	50	+65	49	230	8	50.2	9	39.6	-40	54	-30	55
100	1	21.5	2	42.5	+55	50	+65	49	250	10	10.9	11	10.5	-52	34	-42	35
120	3	32.8	4	35.1	+45	10	+55	09	290	14	9.5	15	9.1	-52	34	-42	35
130	4	15.8	5	10.4	+37	46	+47	45	330	16	41.5	17	24.3	-25	46	-15	47
140	4	49.7	5	38.3	+29	50	+39	49	Lat. -10°								
160	5	40.0	6	21.9	+12	40	+22	39	30	19	55.7	20	38.5	+15	47	+25	46
180	6	20.0	6	59.9	- 4	59	+ 4	59	50	20	50.2	21	39.6	+30	55	+40	54
200	6	58.0	7	39.9	-22	39	-12	40	70	22	10.9	23	10.5	+42	35	+52	34
220	7	41.7	8	30.3	-39	49	-29	50	90	0	7.3	1	12.7	+47	17	+57	17
240	8	44.8	9	47.1	-55	09	-45	10	110	2	9.5	3	9.1	+42	35	+52	34
250	9	32.7	10	45.1	-61	22	-51	23	130	3	40.4	4	29.8	+30	55	+40	54
260	10	37.5	11	58.5	-65	49	-55	50	150	4	41.5	5	24.3	+15	47	+25	46
270	11	56.8	13	23.2	-67	24	-57	25	190	6	2.2	6	43.4	-18	32	- 8	33
280	13	21.2	14	42.7	-65	49	-55	50	210	6	37.3	7	24.1	-36	13	-26	14
300	15	33.0	16	35.0	-55	09	-45	10	230	7	20.1	8	20.7	-53	39	-43	40
340	16	49.6	17	38.3	-39	49	-29	50	250	8	30.8	10	7.8	-69	25	-59	26
340	17	40.0	18	22.0	-22	39	-12	40	270	11	32.8	13	47.2	-77	39	-67	40
Lat. $\pm 10^\circ$									310	16	59.3	17	59.9	-53	39	-43	40
10	18	2.2	18	43.4	+ 8	33	+18	32	350	18	36.6	19	17.8	-18	32	- 8	33

magnitudes 7.0 and 8.25 in different galactic longitudes. For this figure, however, to facilitate comparison, proportions are used rather than numbers of stars. The light horizontal line indicates for each curve the average number of stars in that particular spectral class and latitude belt. Each plotted point, therefore, represents the ratio of the number of stars in the corresponding longitude to the average number for all longitudes. The fields at $+10^\circ$ and -10° were combined for each class in computing these general averages.

Some further notes and conclusions based on the tables and curves are summarized in the following paragraphs.

1. In this discussion of 11,030 stars brighter than magnitude 8.25, we have included about sixty-five per cent of the area between galactic latitudes $+5^\circ$ and -5° , thirty per cent between latitudes $+5^\circ$ and $+15^\circ$, and nearly forty per cent

TABLE II

NUMBER OF STARS IN EACH SPECTRAL CLASS IN DIFFERENT LONGITUDES

Gal. Lat.	Gal. Long.	Magnitudes brighter than 6.0						Magnitudes 6.0 to 7.0						Magnitudes 7.0 to 8.25						Total Number
		B	A	F	G	K	M	B	A	F	G	K	M	B	A	F	G	K	M	
0	0	1	7	2	1	2	0	1	12	2	1	9	1	6	34	6	18	41	9	153
0	20	2	6	0	2	6	0	6	21	3	6	12	4	9	69	13	20	51	7	237
0	30	5	10	5	2	5	1	6	28	8	5	17	6	13	126	13	32	87	16	385
0	40	6	7	0	3	5	2	5	29	4	2	12	2	19	99	9	15	56	19	294
0	50	4	10	2	2	6	3	4	29	2	4	18	6	20	113	12	29	59	10	333
0	60	6	8	2	0	3	1	5	19	3	1	12	4	8	115	20	18	64	17	306
0	80	2	1	1	4	4	2	12	14	4	2	13	4	16	75	13	21	52	7	247
0	100	2	4	0	0	2	0	5	20	3	2	9	2	26	84	19	34	55	15	282
0	120	6	6	2	2	2	0	2	4	4	5	3	0	6	41	10	23	42	3	161
0	130	2	6	0	4	2	0	2	5	5	4	4	1	9	58	14	23	45	9	193
0	140	2	9	1	0	3	1	3	11	3	5	13	3	14	60	15	25	50	8	226
0	160	7	9	2	2	2	2	3	14	1	4	18	1	7	58	15	18	58	6	227
0	180	5	4	2	1	5	0	5	17	3	2	12	1	12	61	9	13	44	7	203
0	200	4	4	4	2	3	1	6	13	3	2	16	1	11	60	10	12	47	13	212
0	220	7	5	3	1	6	4	8	12	3	3	21	6	16	82	14	18	68	20	297
0	240	7	9	3	1	3	0	7	15	4	0	7	1	10	69	23	22	54	16	251
0	250	4	7	1	3	5	4	15	16	4	2	14	4	34	92	19	16	72	23	335
0	260	12	9	1	8	3	2	16	16	5	1	8	6	71	115	12	17	62	34	398
0	270	8	6	3	5	4	3	10	13	4	7	10	0	40	75	19	20	43	16	286
0	280	3	2	3	3	1	2	6	9	2	5	14	0	16	81	16	29	66	11	269
0	300	5	2	0	1	4	2	2	9	6	0	8	2	21	74	8	19	53	22	238
0	320	5	3	1	1	3	1	7	14	2	6	12	4	25	67	18	26	43	15	253
0	340	1	3	0	1	4	1	8	7	1	0	4	0	25	36	7	12	27	9	146
+10	10	0	6	1	0	2	0	1	18	3	2	4	1	1	52	9	18	36	16	170
+10	50	2	8	1	4	7	0	3	16	2	0	10	5	2	57	15	23	59	15	229
+10	90	0	4	0	1	2	0	1	16	4	3	10	0	4	38	10	14	43	8	158
+10	130	0	4	0	2	0	1	3	6	4	3	10	1	1	55	15	16	52	7	180
+10	150	0	4	0	1	3	0	0	9	3	6	10	2	2	70	10	17	56	7	200
+10	170	1	4	1	1	7	1	0	5	5	3	7	6	1	60	9	27	55	8	201
+10	210	2	3	0	2	2	1	3	11	4	1	5	2	2	47	15	13	46	25	184
+10	230	0	0	1	3	6	0	1	16	1	5	8	0	3	43	11	14	63	22	197
+10	250	0	3	2	0	4	1	0	11	4	2	11	4	11	56	19	16	64	19	227
+10	290	11	7	1	1	7	0	4	10	1	3	9	1	1	41	6	19	54	10	186
+10	330	1	1	2	1	3	1	1	10	2	3	8	1	1	28	12	20	38	8	141
-10	30	3	3	1	1	4	0	4	21	1	3	15	6	1	72	10	14	53	19	231
-10	50	3	4	4	0	1	2	1	10	2	5	6	2	5	70	21	23	65	13	237
-10	70	3	4	4	0	5	2	3	8	0	7	14	3	8	107	16	19	50	25	278
-10	90	6	5	1	1	4	0	4	14	2	4	11	3	7	94	14	22	60	13	265

TABLE II—Continued

Gal. Lat.	Gal. Long.	Magnitudes brighter than 6.0						Magnitudes 6.0 to 7.0						Magnitudes 7.0 to 8.25						Total Number
		B	A	F	G	K	M	B	A	F	G	K	M	B	A	F	G	K	M	
°	°																			
−10	110	1	2	1	3	7	1	3	11	5	4	5	1	3	70	9	23	42	9	200
−10	130	4	2	1	3	3	0	5	6	6	3	7	1	1	42	16	21	31	12	164
−10	150	4	4	2	2	4	0	3	7	2	1	7	1	4	27	12	17	17	3	117
−10	190	3	7	0	0	8	2	5	20	3	0	12	4	3	42	11	8	33	7	168
−10	210	9	2	0	1	4	3	19	17	6	6	6	2	8	61	15	19	61	21	260
−10	230	15	3	0	2	6	4	19	15	2	3	11	0	23	79	21	16	59	8	286
−10	250	2	3	3	2	7	1	2	27	4	0	7	2	3	85	16	8	55	14	241
−10	270	4	2	1	0	9	2	1	17	1	5	7	2	8	73	10	27	49	17	235
−10	310	4	4	0	1	7	1	2	11	2	1	5	3	13	56	14	19	48	7	198
−10	350	2	3	2	2	1	0	1	8	1	1	5	0	4	40	12	11	45	7	145

between latitudes -5° and -15° . Statistical discussions based on the Henry Draper Catalogue cannot safely go to fainter limits than magnitude 8.25.

2. The distribution of stars of Class B for the whole sky has been discussed in Harvard Circular 239; a later Circular will consider the distribution for all known stars of Class M. The irregularities shown in Figure 2 for B stars have little weight as the number involved in the present survey is relatively small.

3. Combining all longitudes, we find from Table II that the average numbers of stars for each spectral class and belt of latitude, in a field of one hundred square degrees, are as follows for magnitudes 7.0 to 8.25:

Spectrum	+10°	0°	-10°
B	3	19	6
A	50	76	66
F	12	14	14
G	18	21	18
K	51	54	48
M	13	14	12
Number of Fields	11	23	14

The numbers above were used in the construction of Figure 2. Even within this narrow belt they show the galactic concentration, particularly for Classes B and A.

4. By computing for all magnitudes the average number of stars in a field, the concentration to the galactic circle appears as follows:

Spectrum	+10°	0°	-10°
B	6	30	16
A	65	97	83
F	16	19	18
G	22	26	22
K	64	69	61
M	16	18	16

The local system is probably responsible for the greater number of B and A stars in southern galactic latitudes.

5. Of the 8,434 stars included in Figure 2, 3,209 or thirty-eight per cent are of Class A, and 2,472 or twenty-nine per cent are of Class K. This indicates that these two classes definitely predominate in the nearer parts of the Milky Way (distance between 100 and 500 parsecs) in so far as stars of the ordinary catalogues are concerned. Dwarf K stars in that region would be of the twelfth apparent magnitude or fainter.

6. Both the A and K stars in Figure 2 clearly show a deficiency in the region of the Taurus nebulosities, latitude -10° , longitude 130° to 170° . Brighter A and K stars in this region show little or no effect of the obscuration. Classes F and G also are unaffected. We conclude that the majority of F and G stars in this magnitude interval are dwarfs, and that a large number of the K stars are giants. Assuming an absolute magnitude $+1.0$ for the A and K stars occulted by the cloud, we compute that the distance of the obscuration is not over 250 parsecs, in essential agreement with estimates made by Dyson and Melotte, Pannekoek, and Seares.

7. The conspicuous deficiency of stars of all spectral classes between longitudes 340° and 20° on the galactic equator appears both in Figure 1 and Figure 2; it marks the great rift in the Milky Way. Table II also appears to show the same effect slightly for the stars brighter than the seventh magnitude.

8. The relatively near star clouds in Cygnus appear to affect only Class A stars to an appreciable extent; and the Class B stars alone show the richness of the Carina region. In fact, one of the striking results of this investigation is the remarkable uniformity, except for the details noted, in the galactic distribution of all spectral classes but M. It is well known that if we go somewhat deeper into space the approximate uniformity with respect to longitude no longer holds.

HARVARD COLLEGE OBSERVATORY

CIRCULAR 241

VARIABLE STARS. PREDICTED MAXIMA AND MINIMA IN 1923

By LEON CAMPBELL

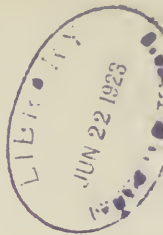
Predicted dates of maxima and minima for variable stars of long period are given in the following table. The successive columns contain the designation number, the name, and the dates for 366 variables.

Des.	Name	1923		Des.	Name	1923		Des.	Name	1923	
		Max.	Min.			Max.	Min.			Max.	Min.
000339	V Scl	<i>m d</i> 2 15	<i>m d</i> 8 5	011208	S Psc	<i>m d</i> 10 1	<i>m d</i> 5 14	031401	X Cet	<i>m d</i> 1 26	<i>m d</i> 5 6
"	" "	12 8	...	011272	S Cas	8 8	...	"	" "	7 21	10 29
001032	S "	12 24	7 9	011712	U Psc	3 14	5 23	032043	Y Per	3 20	8 7
001046	X And	10 27	6 1	"	" "	9 3	11 12	032335	R "	4 20	1 10
001726	T "	6 10	1 21	012350	RZ Per	3 29	11 4	"	" "	11 16	8 8
"	" "	...	10 29	012502	R Psc	5 24	12 2	035124	T Eri	1 2	5 2
001755	T Cas	8 13	...	013238	RU And	7 10	3 24	"	" "	9 11	...
001838	R And	3 7	11 7	"	" "	...	11 22	040725	W "	1 9	9 1
001862	S Tuc	7 25	4 10	013338	Y "	8 26	5 27	042209	R Tau	7 14	3 31
"	" "	...	12 6	"	" "	...	12 31	042215	W "	5 16	1 26
001909	S Cet	11 6	5 24	014958	X Cas	5 10	10 17	"	" "	...	10 19
002438a	T Scl	6 16	2 21	015354	U Per	11 12	8 6	042309	S "	6 29	12 31
"	" "	...	9 11	015912	S Ari	5 17	1 22	043065	T Cam	6 14	12 31
002546	T Phe	7 19	3 11	"	" "	...	11 10	043208	RX Tau	5 17	10 31
"	" "	...	12 16	021024	R "	5 6	2 10	043263	R Ret	6 21	2 20
003179	Y Cep	3 24	9 25	"	" "	11 8	8 15	"	" "	...	11 23
004047	U Cas	5 22	2 1	021143a	W And	11 11	5 25	043274	X Cam	4 16	1 27
"	" "	...	11 5	021281	Z Cep	2 3	7 3	"	" "	9 6	6 19
004132	RW And	10 16	4 24	"	" "	11 14	...	"	" "	...	11 9
004435	V "	1 21	5 28	021403	o Cet	4 2	10 23	043562	R Dor	7 24	3 26
"	" "	10 9	...	022000	R "	4 26	1 29	043738	R Cae	2 25	11 2
004435	X Scl	7 9	3 21	"	" "	10 10	7 15	044349	R Pic	4 8	2 9
"	" "	...	11 26	"	" "	...	12 29	"	" "	9 21	7 25
004533	RR And	1 7	7 6	022150	RR Per	3 6	11 6	044617	V Tau	6 9	3 11
"	" "	12 10	...	022426	R For	9 12	3 6	"	" "	11 26	8 28
004746a	RV Cas	11 24	7 18	022813	U Cet	7 10	3 12	045307	R Ori	7 28	3 7
004958	W "	3 25	10 21	"	" "	...	11 3	045514	R Lep	11 22	3 7
005475	U Tuc	4 28	9 15	022980	RR Cep	7 8	1 4	050003	V Ori	6 29	3 18
010102	Z Cet	4 15	1 22	023133	R Tri	7 6	3 12	050022	T Lep	1 20	7 12
"	" "	10 17	7 26	"	" "	...	12 3	050848	S Pic	...	8 23
010630	U Scl	11 12	7 17	024356	W Per	6 19	12 6	050953	R Aur	...	6 15
010940	U And	5 24	1 16	025050	R Hor	9 9	4 2	051247	T Pic	1 26	5 10
"	" "	...	12 31	025751	T "	3 14	7 7	"	" "	8 14	11 26
011041	UZ "	2 19	9 2	"	" "	10 18	...	051533	T Col	1 30	6 4
"	" "	12 26	...	030514	U Ari	5 30	12 16	"	" "	9 12	...

Des.	Name	1923		Des.	Name	1923		Des.	Name	1923	
		Max.	Min.			Max.	Min.			Max.	Min.
052036	W Aur	<i>m d</i> 1 26	<i>m d</i> 7 8	082476	R Cha	<i>m d</i> 8 3	<i>m d</i> 3 16	122803	Y Vir	<i>m d</i> 4 26	<i>m d</i> 1 19
"	"	10 29	...	083019	U Cnc	5 25	1 1	"	"	11 30	8 25
052404	S Ori	10 29	4 2	083350	X UMa	4 16	9 3	122854	U Cen	1 17	5 15
053068	S Cam	11 1	5 15	"	"	12 20	...	"	"	8 24	12 20
053531	U Aur	7 4	...	084803	S Hya	1 15	5 7	123160	T UMa	5 20	1 27
054331	S Col	7 24	3 6	"	"	9 27	...	"	"	...	10 11
054615a	Z Tau	8 8	...	085008	T "	2 8	7 7	123307	R Vir	4 2	1 14
054629	R Col	8 21	3 30	"	"	11 24	...	"	"	8 25	6 8
054920	U Ori	8 21	3 24	090024	S Pyx	5 17	1 22	"	"	...	10 31
054974	V Cam	2 20	...	"	"	12 9	8 16	123459	RS UMa	2 7	6 25
055353	Z Aur	3 1	4 22	090425	W Cnc	...	8 12	"	"	10 23	...
"	"	6 20	8 11	091868	RW Car	9 1	4 12	123961	S "	6 11	2 19
"	"	10 9	11 30	092551	Y Vel	3 2	10 30	"	"	...	10 3
055686	R Oct	12 14	7 7	092962	R Car	3 5	9 16	124204	RU Vir	2 9	7 29
060450	X Aur	1 31	4 23	093014	X Hya	7 23	3 26	124606	U "	2 2	5 24
"	"	7 13	10 3	093178	Y Dra	7 16	3 18	"	"	8 28	12 17
"	"	12 23	...	093934	R LMi	3 19	10 19	130212	RV "	...	12 27
061647	V "	8 16	2 18	094023	RR Hya	9 24	4 13	131283	U Oct	1 10	6 29
061702	V Mon	4 14	11 24	094211	R Leo	8 22	3 24	"	"	11 6	...
063159	U Lyn	9 28	5 31	094953	Z Vel	10 4	3 28	132202	V Vir	3 15	7 31
063558	S "	6 9	1 20	095421	V Leo	6 1	2 1	"	"	11 20	...
"	"	...	11 16	"	"	...	10 31	132422	R Hya	1 28	8 18
064030	X Gem	1 22	6 11	095563	RV Car	4 30	12 16	132706	S Vir	3 18	9 14
"	"	10 11	...	100661	S "	5 28	3 9	133155	RV Cen	6 29	...
065111	Y Mon	5 28	2 18	"	"	10 24	8 5	133273	T UMi	6 26	2 6
"	"	...	10 5	"	"	...	12 31	"	"	...	12 20
065355	R Lyn	7 7	1 1	101058	Z "	12 1	6 4	133633	T Cen	3 31	2 19
070109	V CMi	9 30	5 15	101153	W Vel	8 28	4 20	"	"	6 29	5 20
070122a	R Gem	11 26	7 9	103270	RZ Car	3 23	8 20	"	"	9 27	8 18
070310	R CMi	1 18	6 27	"	"	12 20	...	"	"	12 26	11 16
"	"	12 22	...	103769	R UMa	6 3	1 22	134236	RT "	1 18	5 16
070772	R Vol	9 18	...	"	"	...	11 20	"	"	9 23	...
071201	RR Mon	10 15	4 28	104620	V Hya	3 21	12 6	134440	R CVn	3 16	8 15
071713	V Gem	3 5	7 21	104628	RS "	8 24	3 27	134536	RX Cen	11 14	7 16
"	"	12 6	...	104814	W Leo	3 15	11 12	134677	T Aps	8 8	4 18
072708	S CMi	5 21	10 11	110506	S "	3 19	6 17	135908	RR Vir	5 28	3 5
072811	T "	11 12	6 16	"	"	9 25	12 24	"	"	12 31	10 8
072820b	Z Pup	12 2	6 1	111661	RS Cen	4 30	2 19	140113	Z Boo	9 21	6 3
073173	S Vol	12 31	6 22	"	"	10 12	8 3	140512	Z Vir	4 29	1 9
073508	U CMi	12 31	6 24	114441	X "	10 23	6 23	"	"	...	11 14
073723	S Gem	9 3	5 1	115058	W "	2 7	5 24	140528	RU Hya	5 12	11 10
074241	W Pup	4 13	1 24	"	"	8 28	12 12	140959	R Cen	8 16	...
"	"	8 12	5 25	115919	R Com	6 18	2 2	141567	U UMi	4 2	8 28
"	"	12 11	9 23	120012	SU Vir	3 31	1 5	141954	S Boo	4 28	9 2
074323	T Gem	9 13	4 25	"	"	10 22	7 29	142205	RS Vir	3 23	11 8
075612	U Pup	5 5	1 2	120905	T "	8 8	3 11	142539	V Boo	9 1	5 3
"	"	...	11 13	121418	R Crv	2 25	8 22	142584	R Cam	3 9	7 14
081112	R Cnc	3 23	9 19	122001	SS Vir	10 21	4 28	"	"	12 4	...
081617	V "	7 21	3 23	122532	T CVn	7 9	1 16	143227	R Boo	3 24	7 15
"	"	...	12 20	"	"	...	11 2	"	"	11 2	...

Des.	Name	1923		Des.	Name	1923		Des.	Name	1923	
		Max.	Min.			Max.	Min.			Max.	Min.
		<i>m d</i>	<i>m d</i>			<i>m d</i>	<i>m d</i>			<i>m d</i>	<i>m d</i>
143417	V Lib	7 29	5 5	161122b	S Sco	9 23	7 3	175654	V Dra	...	11 11
144918	U Boo	2 1	4 22	161138	W CrB	2 7	6 21	180363	R Pav	6 29	3 21
"	"	7 27	10 15	"	"	10 3	...	"	"	...	11 6
145254	Y Lup	2 16	10 14	161607	W Oph	2 21	9 7	180531	T Her	4 20	1 25
150018	RT Lib	8 2	4 2	162112	V "	8 4	2 21	"	"	10 2	7 9
150519	T "	4 28	1 5	"	"	...	12 20	"	"	...	12 21
"	"	...	8 31	162119	U Her	3 7	11 12	180565	W Dra	3 2	7 23
150605	Y "	8 8	5 10	162319	Y Sco	8 17	2 23	"	"	11 13	...
151520	S "	5 21	2 12	162807	SS Her	1 14	3 5	180666	X "	6 16	3 16
"	"	11 30	8 24	"	"	5 2	6 21	"	"	...	11 28
151714	S Ser	8 9	3 10	"	"	8 18	10 7	181031	TV Her	8 8	3 16
151731	S CrB	1 2	8 30	"	"	12 4	...	181103	RY Oph	5 6	2 22
"	"	12 30	...	162815	T Oph	2 26	10 12	"	"	10 6	7 25
151822	RS Lib	7 15	4 10	162816	S "	6 17	3 5	"	"	...	12 25
"	"	...	11 13	"	"	...	10 25	181136	W Lyr	2 13	5 22
152714	RU "	5 5	11 2	163137	W Her	2 14	7 3	"	"	8 28	12 4
152849	R Nor	...	7 20	"	"	11 21	...	182133	RV Sgr	6 11	11 14
153030	X Lib	3 9	6 11	163266	R Dra	8 30	4 16	182224	SV Her	2 9	6 9
"	"	8 19	11 21	"	"	...	12 18	"	"	10 7	...
153215	W "	2 25	6 5	164319	RR Oph	6 23	2 9	182306	T Ser	2 10	7 30
"	"	9 18	12 27	"	"	...	11 30	183149	SV Dra	3 29	8 17
153378	S UMi	6 11	11 4	164715	S Her	10 3	5 8	"	"	12 12	...
153620	U Lib	2 24	7 17	164844	RS Sco	6 30	3 2	183225	RZ Her	1 13	7 17
"	"	10 8	...	165030	RR "	8 24	4 8	"	"	12 7	...
153654	T Nor	3 11	7 17	165202	SS Oph	3 21	7 29	183308	X Oph	3 11	8 23
"	"	11 10	...	"	"	11 6	...	184134	RY Lyr	4 7	10 9
154536	X CrB	1 15	5 19	165631	RV Her	6 29	3 31	184243	RW "	...	10 15
"	"	9 11	...	"	"	...	10 21	185032	RX "	2 23	6 27
154615	R Ser	2 26	10 19	165636	RT Sco	6 11	...	"	"	10 30	...
154639	V CrB	10 27	6 5	170215	R Oph	9 26	5 22	185512a	ST Sgr	2 19	9 12
154715	R Lib	4 22	8 27	170627	RT Her	9 25	5 4	185634	Z Lyr	6 30	1 31
"	"	12 20	...	170833	RW Sco	4 15	11 21	"	"	...	11 18
154736	R Lup	8 1	4 24	171401	Z Oph	1 14	7 28	185737	RT "	2 24	7 18
155018	RR Lib	4 22	9 16	"	"	12 29	...	"	"	11 1	...
155229	Z CrB	1 31	7 1	171723	RS Her	7 19	4 10	190108	R Aql	6 19	1 26
"	"	10 9	...	"	"	...	11 16	"	"	...	12 31
155823	RZ Sco	3 5	5 26	172486	S Oct	8 6	4 30	190529a	V Lyr	5 8	...
"	"	8 10	10 31	172809	RU Oph	1 21	4 28	190925	S "	8 6	3 29
160031	Z "	11 30	6 24	"	"	8 10	11 15	190933a	RS "	8 26	3 19
160118	R Her	3 14	9 11	173543	RU Sco	12 23	4 27	190941	RU "	12 4	6 7
160210	U Ser	4 18	1 10	174135	SV "	2 25	7 21	190967	U Dra	10 21	5 27
"	"	12 12	9 5	"	"	11 8	...	191007	W Aql	...	10 17
160221a	X Sco	5 28	2 18	174162	W Pav	9 27	6 5	191017	T Sgr	6 9	...
"	"	12 13	9 5	174551	U Ara	7 17	4 14	191019	R "	3 20	7 31
160519	W "	2 21	6 17	"	"	...	11 24	"	"	12 14	...
"	"	10 1	...	175111	RT Oph	2 15	10 13	191319	S "	7 19	3 21
160625	RU Her	3 7	12 20	175458a	T Dra	10 8	4 16	"	"	...	11 6
161122a	R Sco	1 18	6 9	175519	RY Her	5 2	1 12	191321	Z "	2 11	8 20
"	"	8 29	...	"	"	12 10	8 22	191331	SW "	6 18	2 18
161122b	S "	3 30	1 7	175654	V Dra	6 29	2 4	"	"	...	12 4

Des.	Name	1923		Des.	Name	1923		Des.	Name	1923	
		Max.	Min.			Max.	Min.			Max.	Min.
191637	U Lyr	m d	m d	203429	R Mic	m d	m d	215828	S PsA	m d	m d
192928	TY Cyg	11 26	5 24	"	"	7 23	5 19	220412	T Peg	6 12	12 26
193311	RT Aql	7 5	3 7	203611	Y Del	12 8	10 4	220613	Y "	6 20	3 19
193449	R Cyg	7 15	2 5	203816	S "	4 8	...	"	"	...	10 13
193509	RV Aql	7 27	3 27	203847	V Cyg	8 20	4 19	220714	RS "	10 31	7 15
"	"	...	10 31	203905	Y Aqr	12 4	7 7	221230	R PsA	4 14	9 27
193972	T Pav	5 18	2 13	204016	T Del	8 19	3 6	221321	X Aqr	7 14	4 5
"	"	...	10 15	204104	W Aqr	10 29	6 1	"	"	...	11 6
194048	RT Cyg	2 17	5 30	204215	U Cap	4 28	10 20	221938	T Gru	3 25	1 27
"	"	8 26	12 6	"	"	3 15	6 17	"	"	8 9	6 13
194348	TU "	1 7	6 19	204318	V Del	10 3	...	"	"	12 24	10 28
"	"	8 13	...	204405	T Aqr	3 11	...	"	"	12 10	7 21
194604	X Aql	2 7	8 26	"	"	6 9	3 10	221948	S "	9 24	5 27
194632	χ Cyg	11 11	5 15	204846	RZ Cyg	12 29	9 29	222129	RV Peg	1 1	5 14
194659	S Pav	...	7 18	"	"	4 8	6 23	222439	S Lac	8 27	...
194929	RR Sgr	1 16	7 23	204954	S Ind	12 31	...	"	"	1 6	5 12
195142	RU "	1 12	5 24	205017	X Del	1 1	9 15	222867	R Ind	8 10	12 14
"	"	9 11	...	205627	RR Cap	5 15	10 7	"	"	8 30	4 21
195202	RR Aql	7 7	3 19	"	"	4 30	1 30	223462	T Tuc	...	12 28
195308	RS "	10 9	6 7	205923	R Vul	...	10 27	"	"	6 7	9 25
195849	Z Cyg	3 2	8 4	"	"	2 1	4 19	223841	R Lac	7 15	3 1
"	"	11 20	...	"	"	6 18	9 3	225120	S Aqr	...	12 6
200212	SY Aql	3 3	10 12	210124	V Cap	11 2	...	"	"	6 28	3 20
200357	S Cyg	2 13	8 12	"	"	5 23	2 4	225914	RW Peg	...	10 15
200514	R Cap	4 24	11 20	210129	TW Cyg	...	11 6	"	"	4 13	10 17
200715a	S Aql	3 7	5 27	210221	X Cap	...	6 17	230110	R "	5 14	1 21
"	"	7 31	10 20	"	"	3 19	6 15	230759	V Cas	12 29	9 7
"	"	12 24	...	210382	X Cep	10 23	...	"	"	1 22	7 7
200747	R Tel	12 3	6 16	210504	RS Aqr	3 14	...	231425	W Peg	12 30	...
200812	RU Aql	3 5	8 16	"	"	2 19	6 23	"	"	5 28	11 12
"	"	12 4	...	210516	Z Cap	9 21	...	231508	S "	6 18	1 31
200822	W Cap	2 7	6 17	"	"	3 12	6 10	232746	V Phe	...	10 9
"	"	8 30	...	210812	R Equ	9 9	12 8	"	"	9 25	5 30
200906	Z Aql	5 9	3 19	"	"	1 1	5 21	233335	ST And	2 11	8 25
"	"	9 15	7 26	210868	T Cep	9 19	...	233815	R Aqr	4 14	...
"	"	...	12 2	210903	RR Aqr	6 11	11 29	233956	Z Cas	10 1	5 28
200938	RS Cyg	...	6 29	"	"	3 12	5 21	235053	RR "	7 18	3 30
201008	R Del	4 12	9 5	211614	X Peg	9 9	11 18	235150	R Phe	...	12 24
201130	SX Cyg	5 1	...	"	"	6 9	2 9	"	"	1 5	6 9
201139	RT Sgr	1 1	6 12	211615	T Cap	12 26	8 28	235209	V Cet	9 22	...
"	"	10 31	...	"	"	7 28	3 30	"	"	1 16	6 15
201647	U Cyg	7 11	...	212030	S Mic	...	12 24	235265	R Tuc	10 29	...
202240	U Mic	3 4	10 20	"	"	6 2	3 4	"	"	...	9 9
202622	RU Cap	6 30	2 10	213678	S Cep	12 31	10 3	235350	R Cas	2 24	8 8
202817	Z Del	2 13	7 25	214024	RR Peg	...	6 5	235525	Z Peg	1 25	8 23
"	"	12 14	...	214247	R Gru	8 13	4 21	235715	W Cet	3 27	11 12
202954	ST Cyg	2 12	8 19	215605	V Peg	10 15	5 31	235855	Y Cas	6 13	2 9
203429	R Mic	3 7	1 1	215828	S PsA	11 19	5 18	235939	SV And	...	12 20



HARVARD COLLEGE OBSERVATORY

CIRCULAR 242

COMPARISON OF A MILKY WAY FIELD WITH ONE AT THE SOUTH GALACTIC POLE

BY SOLON I. BAILEY

In the present investigation the number of stars in a rich region of the Milky Way is compared with the number of stars in a region at the South Galactic Pole. The photographs were made at Arequipa with the 24-inch Bruce photographic telescope. The longest exposures show stars fainter than the nineteenth photographic magnitude.

Star gauges were made by the Herschels a century ago, and since that time studies of the distribution of stars have been made by Seeliger, Pickering, Celoria, and others. In much of this work great uncertainty existed as to the correct magnitudes of the stars involved. Also, in general, only comparatively bright stars were included.

The completion of the Harvard Photometry enabled Pickering to draw definite conclusions concerning the distribution of the stars included in that work. He reached the somewhat surprising result that the law of distribution of these stars with respect to magnitude was the same for galactic as for non-galactic regions.¹ Also, the number of stars of all the magnitudes involved was found to be a little less than twice as great in the Milky Way as in other parts of the sky. These results were found to be true to magnitude 6.5, and are probably due to the fact that nearly all the stars concerned are members of the local cluster, whose greatest diameter is more or less in the plane of the Galaxy. Pickering was inclined to believe that the same law held true for the much fainter stars of the northern Durchmusterung, and that to magnitude 9.5 there were only twice as many stars in the Milky Way as elsewhere.² The attempt to carry the discussion to magnitude 13 by the use of Hagen's catalogues was confessedly uncertain owing to the small number of stars available.

The work of Argelander, Seeliger, and Celoria indicates that even for stars of the ninth and tenth magnitudes there is a small increase in the proportion of Milky Way stars. The counts of the Herschels gave a maximum of about twenty times

as many stars in the Galaxy as at the galactic poles, but the precise magnitudes attained are not known. Kapteyn's studies of the problem in 1908 showed an increasing galactic concentration with decreasing apparent brightness.³ In these determinations mean results were generally given. Chapman and Melotte have made an extensive investigation of the galactic concentration for the stars to the seventeenth magnitude shown on the Franklin-Adams plates.⁴ Seares has verified Kapteyn's values from studies of Selected Areas and zones of the Astrographic Catalogue.⁵ Pannekoek, Henie, Nort, and others have also contributed to the solution of these problems.

The number of stars in a square degree near the galactic poles is fairly uniform, while the number varies enormously in the Milky Way. In certain deeply obscured regions near the central line of the Galaxy the number is much less than at the poles, while near by the number may be very great.

For the present study the photographic magnitudes determined in the Harvard Standard Regions by Miss Leavitt and Professor Pickering have been used as standards, and the method of limits has been employed to extend the scale to other regions. For this purpose exposures varying from one hour to six hours were made with the Bruce telescope. It has been found in general that an exposure of one second shows stars to about the tenth magnitude, and that tripling the exposure extends the scale by about one magnitude. For exposures of 40 minutes, or less, 8 × 10 Cramer Hi-speed plates were used, and for longer exposures, 14 × 17 Seed Gilt Edge 30.

Some details of the results obtained for the limiting magnitudes from different exposures are given in Table I. The Standard Regions photographed were those at 13^h, +15°; 19^h, +15°; and 22^h 40^m, -45°. In each case the faintest stars whose

TABLE I

Exposures		Mean Lim. Magn.	Residuals	Accepted Magns.
<i>m</i>	<i>s</i>			
0	1	10.1	0, 0, 1, 0	10.1
0	3.3	11.3	1, 1, 0, 0	11.2
0	10	12.3	2, 0, 1, 1	12.4
0	30	13.6	3, 2, 1, 3	13.5
1	29	14.7	3, 2, 0, 2	14.6
4	27	15.5	1, 2, 4, 1	15.6
13	20	16.4	3, 2, 1, 4	16.5
40	0	17.3	1, 1	17.4
120	0	18.4	0, 0	18.3
360	0	..	.....	(19.2)

images were distinctly visible were accepted. The first column gives the length of the exposure, the second, the mean limiting magnitude, and the third column, the residuals from the mean for the individual plates, expressed in tenths of a magnitude. A smooth curve was then drawn through the mean magnitudes, the deviations from which were no greater than the probable errors of the observations. The smooth curve, therefore, has been taken to represent the most probable relation between the length of exposure and the corresponding limiting magnitudes. The final column gives the accepted magnitudes for the different exposures.

No standards were available fainter than magnitude 19.0, but a slight extension of the curve seems permissible. Precisely the same exposures, under as nearly equal conditions as possible, were made on the other regions under consideration, and it is believed that the scale of the Standard Regions has been preserved without serious modification. In any case, the results are fairly comparable, since the exposures are the same on all the regions. The plates were taken when the fields were as near the zenith as possible, but a correction for atmospheric absorption was made in the few cases where it amounted to one tenth of a magnitude, or more.

The present paper deals with extremes. One of the richest star fields of the Milky Way was selected for comparison with the region of the South Galactic Pole, which may be regarded, perhaps, as a standard of reference. For the purposes of the count a reticule was used, made by Señor Muñiz of the Arequipa staff, having a square of such a scale as to cover one square degree on the Bruce plates. This square, 60 millimeters on a side, is divided into 3,600 small squares. The lines, though distinct, are fine so that the occultation of faint objects is reduced to a minimum. Only images which appeared to be surely stellar were included in the counts. When the stars in the square degree amounted to a thousand, or less, all the stars were counted; but on plates having a greater number of stars, only those in every fifth square were counted and the results were multiplied by five.

It is probable that the number of stars counted is slightly less than the true number, especially when the stars are very numerous. In the region chosen to represent the Milky Way the distribution of the stars is very uniform, and there is little overlapping of images. Even with the longest exposures the capacity of the Bruce plates is by no means exhausted. The images of the faintest stars have a diameter of 3" or 4". The scale of the plates is 1 mm. = 60". Hence, aside from the brighter stars, whose images are much larger, if there were no inequalities of distribution, nearly a million stars per square degree would be needed to shade completely the background of the plate. Even including the brighter stars, much less than half the surface is covered with distinct star images.

The area selected in the Galaxy is the square degree in Sagittarius whose center is at R.A. $18^h 8.5^m$; Dec. $-30^\circ.4$ (1900). The South Galactic Pole was assumed to be at R.A. $0^h 40^m$; Dec. -28° . Table II contains the results of the counts on the two series of plates. The first column gives the exposures, the second, the limiting magnitudes, the third and fourth, the number of stars counted on the galactic and polar plates, respectively, and the fifth column, the ratio between the number of stars in the two regions. In all cases in this table the number is the whole number of stars of the given magnitude, and brighter.

TABLE II

Exposures		Limiting Magns.	Number of Stars		Ratio
			Galaxy	Pole	
<i>m</i>	<i>s</i>				
0	1	10.1	13	5	2.6
0	3.3	11.2	47	13	3.6
0	10	12.4	111	29	3.8
0	30	13.5	349	62	5.6
1	29	14.6	1945	104	18.7
4	27	15.6	9160	151	60.7
13	20	16.5	21895	225	97.3
40	0	17.4	36260	359	101.0
120	0	18.3	57130	494	115.6
360	0	19.2	61595	551	111.8

On the polar plate of six hours exposure, 27 faint nebulae were seen, 4 of which were distinctly spiral. These were in addition to the stars counted, a few of which may possibly be nebulous. The background appears uniformly dark.

From Table II it is seen that, including all stars of magnitude 10.1, and brighter, the number in the Milky Way is only about two and a half times that at the Pole. This result agrees well with the previous determinations of the distribution of the brighter stars referred to above. After the thirteenth magnitude the ratio increases with great rapidity, and after the seventeenth magnitude it amounts to more than 100.

If the stars were everywhere as dense as in this area of the Galaxy, the whole sky would contain two and a half billions of stars to the nineteenth magnitude; if of the same density as at the South Galactic Pole, about twenty-three millions. It will be noted that the number of stars falls off rapidly on the last plates of 360 minutes exposure. This is especially striking in the galactic area. A careful comparison of the plates of 120^m and 360^m exposure confirms the counts. The

plates appear to be of equal quality. The result may indicate either that we are approaching the limits of the galactic system or that the view of more distant stars in this region is partially obstructed by an obscuring medium. Nevertheless, parts of the plates of the galactic area observed show an irregular darkening of the background, undoubtedly caused by still fainter stars.

If for each region we plot the numbers of stars in relation to the magnitudes, smooth curves may be drawn through them, the deviations from which are no greater, perhaps, than the accidental errors of the observations, although in the galactic region there is an indication of an excess of stars of about magnitude 16.5 and a relative paucity of stars at 17.5. The areas concerned are rather small and slight changes of position would doubtless give somewhat different results. Assuming, therefore, that the smooth curves represent the distribution of the stars for the two regions, we can derive from them the approximate number of stars of any magnitude. Grouping the stars so that under 10.0 all stars from 9.5 to 10.5 are included, and in a similar manner for 11.0, etc., we obtain the results given in Table III. The first column contains the different groups referred to above, except that the first line contains all stars of magnitude 9.5, and brighter. The second and third columns contain the number of stars thus derived for the galactic and polar regions for the different magnitude groups, and the fourth column, the ratio between them. The fifth and sixth columns give the ratio of the number of stars of each magnitude to the number in the preceding, brighter group for each region, and the seventh and eighth columns, the proportion of the number of stars in each magnitude interval to the whole number of stars of all magnitudes.

TABLE III

Magn.	Number of Stars		Ratio, Galaxy to Pole	Ratio, Each to Preceding Magn.		Percentage of all	
	Galaxy	Pole		Galaxy	Pole	Galaxy	Pole
]9.5	6	3	2.0	..	..	00+	01-
10.0	15	5	3.0	..	..	00+	01-
11.0	37	6	6.2	2.5	1.2	00+	01+
12.0	63	17	3.7	1.7	2.8	00+	03+
13.0	228	31	7.4	3.6	1.8	00+	06-
14.0	1151	38	30.3	5.0	1.2	02-	07-
15.0	6850	46	149.	6.0	1.2	11-	08+
16.0	12750	79	161.	1.9	1.7	20+	14+
17.0	17900	152	118.	1.4	1.9	29-	27+
18.0	19800	136	146.	1.1	0.9	32-	24+
19.0	3500	49	71.	0.2	0.4	06-	09-

From the fourth column of Table III it appears that while, for stars of magnitude 9.5 and brighter, the number in the galactic area is only twice that at the Pole, the ratio increases rapidly for fainter stars until the maximum is reached at the seventeenth magnitude, where the number of stars in the Galaxy is about one hundred and sixty times that at the Pole.

The ratio of the number of stars of each magnitude to the number of the next brighter magnitude is small and fairly uniform to the eighteenth magnitude at the Pole. In the Galaxy the ratio increases rapidly from the twelfth to the fifteenth magnitude, after which there is a rapid decrease; possibly this indicates the existence of a distinct star cloud, as suggested by Pannekoek from analogous data for another region in the Milky Way.⁶

In both regions the number of stars of the nineteenth magnitude appears to be very small compared with the preceding groups, but the uncertainty of the magnitude scales at this point must be kept in mind.

NOTE ON THE STRUCTURE OF THE MILKY WAY

Astronomers in the past have generally regarded the Milky Way as an irregular, luminous belt of stars encircling the sky, broken in many places by extended areas vacant in stars. More recently the idea has been growing that the dark spaces of the Milky Way are associated with obscuring nebulosities. Apparently the time has now come to accept definitely the reality and dominating significance of these occulting nebulosities. For many years Barnard has called attention to this subject, and other astronomers have given it serious consideration. The region of Rho Ophiuchi is one of the most interesting examples of such an obscuring medium. The Coal Sack, adjacent to the Southern Cross, is an even more famous dark area, popularly supposed to be almost starless.

The sky of the Arequipa Station of the Harvard Observatory, at its best, is probably unsurpassed by that of any other astronomical observatory. The Bruce 24-inch telescope, owing to its considerable power and its large field of good definition (about 5° square), is, therefore, an exceptional instrument for the investigation of faint nebulosities. During the present year a number of long exposures, extending in some cases to ten hours, have been made along the southern Milky Way, especially in the dark areas of the Coal Sack and the Great Rift, which reaches from Centaurus to Cygnus and has many ramifications.

It is not so much that these photographs show numerous individual nebulae, nor that the number of such objects revealed throughout the whole Milky Way, by

the work of Barnard and others, is very great; the fact of special importance is that the Arequipa photographs appear to demonstrate the existence of a faint nebulosity almost universally extended throughout the dark areas, which becomes, therefore, one of the fundamental causes of the familiar appearance of the Milky Way. These obscuring clouds appear to be a principal cause of the irregularities of structure, including the Coal Sack and the Great Rift, and the numberless smaller rifts and holes, which are partly visible to the naked eye and are revealed in marvelous intricacy in photographs of long exposure. Although they often entirely obscure more distant stars, these clouds, at least in many cases, are not completely dark. If this were true, it would be difficult to determine whether the appearances are caused by lack of stars or by an obscuring medium. The clouds are often faintly but irregularly luminous, showing details of structure which establish with certainty their nebulous character.

We may conclude, therefore, that not only is the Milky Way a galaxy of stars forming a great and brilliant belt around the sky, but that, associated and interwoven with it in endless profusion and cutting off in part our view of the real galactic system, is an almost equally vast and irregular belt of obscuring nebulosities.

Striking differences in the appearance of various regions of the Milky Way are doubtless caused by the clustering tendency of the stars, by the lack of a central point of view, and perhaps for other reasons; nevertheless, if for a moment we could eliminate the zone or zones of nebulosity and see the Galaxy as it really is, we should probably behold a zone of faint stars, little if at all broken by rifts or holes, and without definite limits in width. The number of stars in this system is at least five hundred millions, many of which, in the more condensed portions, are now obscured from our view.

In many cases the distances of these dark clouds are relatively small and can be determined with reasonable approximation by a study of the number and magnitudes of the unobscured stars, or by the other methods outlined by Lundmark.⁷ Other and more remote nebulosities may also exist, obscuring in whole or part the light of the most distant stars.

Whether such nebulosities exist at high galactic latitudes remains to be determined. Photographs of long exposure already obtained at this observatory give negative results. To be conclusive, the galactic latitude of the regions investigated should not be less than 50° . The 182 dark markings in the sky, listed by Barnard,⁸ are all within about 20° of the galactic equator. Our own point of view is influenced by the local cluster in which the Sun is found, but counts of

faint stars make it certain that the influence of the Galaxy covers nearly the whole sky.

It is shown above that the number of stars in Sagittarius is about one hundred and ten times that at the pole, when all stars to magnitude 19.2 are included. If the doubtful assumption is made that in a large way the distances are proportional to the number of stars, a moderate estimate of the most distant stars in the galactic area would be 300,000 light years, assuming 3,000 light years for the farthest stars at the pole. The Sagittarius region has a galactic latitude of about 7° . At a distance of 300,000 light years the stars would be about 35,000 light years distant from the central plane of the Galaxy. We would thus have an improbable galactic system with a thickness of some 6,000 light years near the Sun and of 70,000 light years near the apparent borders.

Stars of apparent magnitude 19.2 are shown on Bruce plates of six hours exposure. Stars of apparent magnitude 19.2 would be of absolute magnitude 5.0 at a distance of about 30,000 light years, and of zero absolute magnitude at about 300,000 light years. At great distances, therefore, only giant stars will appear on Bruce plates of six hours exposure.

In studies of the distribution of special stars, e.g. novae, perhaps not enough attention has been given to the density of the stars in different regions. If any such objects occur by chance, according to the number of stars, one might expect to find a hundred times as many for a given area in certain parts of the Galaxy as at the poles.

NOVEMBER 25, 1922.

1. *H. A.* **48**, 166, 1903.
2. *ibid.*, p. 171.
3. *Gron. Pub.*, No. 18, 1908.
4. *Mem. R. A. S.* **60**, Part IV, 1914.
5. *Mt. W. Commun.*, No. 43, 1917; *Mt. W. Contr.*, No. 135, 1917.
6. *M. N.* **79**, 500, 1919.
7. *Pub. A. S. P.* **34**, 40, 1922.
8. *Ap. J.* **49**, 1, 1919.

HARVARD COLLEGE OBSERVATORY

CIRCULAR 243

DISTANCES OF TWO HUNDRED AND THIRTY-THREE SOUTHERN STARS

BY HARLOW SHAPLEY AND ADELAIDE AMES

1. The problem of the distances and distribution of the stars is beginning to resolve itself into the two-fold task of sorting them into categories of absolute magnitude (guided chiefly by spectral class), and of measuring the apparent magnitudes. In the near future the determination of accurate apparent magnitudes is likely to become the more important and urgent of these two problems.

Because of outstanding errors, both in the photometric scales and in the individual estimates of brightness, the absolute magnitudes for most classes of stars can already be estimated as accurately as the apparent magnitudes are known, except, perhaps, for the very brightest stars. Recent extensive investigations of proper motions and trigonometric parallaxes have brought about this fairly favorable situation with regard to absolute brightness. For stars fainter than the eighth apparent magnitude the present uncertainties in apparent brightness will make further refinement of the mean absolute magnitude of little immediate value for many spectral classes.

Since the average intrinsic luminosity is known for several types, it is possible to construct a small table, based indirectly on the apparent magnitudes and spectra given in the Henry Draper Catalogue, that will give the distribution of the distances of more than one hundred thousand stars with sufficient accuracy for many statistical purposes (Table I). Most of the F stars in the Henry Draper Catalogue are dwarfs; the A, K, and M stars are mainly giants.

The recently published discussions of absolute magnitudes by Lindblad, Curtis, Seares, Lundmark, and Adams and Joy, and some unpublished investigations of trigonometric parallaxes by Luyten, have been of service in deriving the adopted absolute magnitudes given in the second column of Table I. The quantities in the following columns are limits of distance in parsecs and the corresponding number of stars taken from a tabular summary published in Harvard Circular 226.

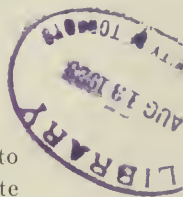


TABLE I
THE DISTANCES OF 105,529 STARS

Spectral Class	Absolute Magnitude	Intervals of Visual Magnitude			
		6.26 to 7.25	7.26 to 8.25	8.26 to 9.25	6.26 to 9.25
BS, 9	0.0 $\pm$ 0.4	150-340 1,302	235-540 2,500	375-850 4,666	8,468
A0	0.6 $\pm$ 0.4	110-255 1,400	180-405 4,184	285-645 11,016	16,600
A2, 3	1.2 $\pm$ 0.4	85-195 1,184	135-310 3,296	215-490 7,766	12,246
A5	1.7 $\pm$ 0.45	65-160 280	105-250 824	165-395 1,896	3,000
F0	2.4 $\pm$ 0.4	50-110 688	80-180 2,232	125-280 4,024	6,944
F2	2.8 $\pm$ 0.4	40-95 512	65-150 1,320	105-235 2,768	4,600
F5	3.4 $\pm$ 0.35	30-70 728	50-110 2,496	80-175 5,824	9,048
K0	0.6 $\pm$ 0.4	110-255 2,656	180-405 7,536	285-645 14,616	24,808
K2	0.5 $\pm$ 0.3	125-255 568	195-405 3,208	310-645 5,920	9,696
K5	0.2 $\pm$ 0.3	140-295 512	225-470 2,040	355-745 4,800	7,352
M	0.0 $\pm$ 0.3	155-325 403	245-515 998	390-815 1,366	2,767

The tabulated limits of distance, for a given spectrum and interval of apparent magnitude, are computed after adding the value of its estimated probable error to the adopted absolute magnitude for the lower limit, and subtracting the probable error from the adopted absolute magnitude for the upper limit. Thus, the modulus for the first lower limit of distance in the table is $M - m = 0.0 + 0.4 - 6.26$, and for the upper limit, $M - m = 0.0 - 0.4 - 7.25$. It is believed that nearly ninety per cent of the stars of a given type and magnitude-interval fall within the corresponding tabulated limits of distance. Possibly the percentage should be placed at eighty for the K0 and K2 stars fainter than the seventh magnitude, where an increasing admixture of dwarfs appears.

To the above tabulation, the stars of Classes B0 – B5 might be added, assigning them a mean absolute magnitude somewhere between -0.5 and -1.5 . We might also add the N stars, and O stars, and other small groups for which the mean absolute magnitudes have been determined from the proper motions. For the stars of spectral classes F8, G0, and G5, the dispersion in absolute magnitude is thought to be too large to permit their inclusion in such a table.

Since nearly all of the tabulated stars have parallaxes less than a hundredth of a second of arc, the accuracy of the distances given in Table I is undoubtedly higher than that now possible for trigonometric work; and, for the great majority of these stars, even the spectroscopic parallaxes will bring little improvement beyond the purifying of the groups through the elimination of the few exceptional stars.

2. Notwithstanding the evidence that the problem of distances is destined hereafter to consist largely in standardized photometry and the rough sorting of color or spectral species, it is of interest and importance to determine the individual parallaxes as accurately as possible, both for the stars of abnormal or special types, and for the brighter and nearer stars, for which the present measures of apparent magnitude justify attempts at higher precision in absolute luminosity.

The photographic spectra collected at Harvard are now being used to obtain absolute magnitudes and parallaxes of the brighter stars. Special attention is directed to stars in the southern hemisphere, and to those spectral classes wherein the absolute magnitude appears to have a considerable dispersion about its mean value. Parallaxes have been previously given for 137 stars, mostly of spectral class K0, in Harvard Circulars 228 and 232, where the Mount Wilson system of spectroscopic absolute magnitudes was used as a basis for the Harvard determinations.

The present paper contains results for 233 stars, which are all in the southern hemisphere and classed as K0 in the Henry Draper Catalogue. The average apparent brightness is slightly fainter than the fifth visual magnitude. The absolute magnitudes are determined from estimates of the relative intensity of the lines 4215 and 4326 on one-prism photographs made with the 13-inch Boyden telescope at Arequipa. For ordinary giant stars the estimates of intensity fall into only four groups, but the combination of additional plates and second readings gives many intermediate values of the mean intensity. It is believed that neither the method nor the photographs justify closer classification of the relative intensity. Some details of the spectra are given in Harvard Bulletin 788, where the relation of line intensity to mean proper motion is discussed.

TABLE II
PARALLAXES AND ABSOLUTE MAGNITUDES FOR 121 SOUTHERN STARS OF CLASS K

No.	H.D.	R.A. 1900		Dec. 1900	Vis. Mag.	Abs. Mag.	Rel. Wt.	π	No.	H.D.	R.A. 1900		Dec. 1900	Vis. Mag.	Abs. Mag.	Rel. Wt.	π
		<i>h</i>	<i>m</i>	<i>o</i>	<i>i</i>			<i>"</i>			<i>h</i>	<i>m</i>	<i>o</i>	<i>i</i>			<i>"</i>
1	496	0	4.3	-46 18	3.9	+0.2	3	.018	155	88323	10	5.9	-65 19	5.4	0.0	2	.008
138	636	0	5.5	-82 47	5.3	+0.3	2	.010	156	89682	10	15.8	-54 32	4.6	-0.3	2	.011
2	2261	0	21.3	-42 51	2.4	+1.2	3	.056	157	94510	10	49.4	-58 19	3.9	+1.3	4	.030
3	3919	0	36.6	-46 38	4.6	+0.3	2	.013	158	94890	10	52.1	-36 36	4.7	+0.5	3	.014
139	5437	0	51.0	-11 49	5.5	+1.5	2	.016	159	99322	11	20.6	-35 31	5.3	+0.7	2	.012
140	6055	0	56.7	-39 28	5.6	+3.1	2	.032	35	105707	12	5.0	-22 4	3.2	+0.1	3	.024
141	6245	0	58.3	-46 56	5.3	+1.1	2	.014	160	110458	12	37.1	-48 16	4.6	+0.3	2	.013
4	6595	1	1.6	-47 15	3.4	+0.6	3	.028	161	110829	12	39.7	-60 26	4.7	+1.6	2	.024
142	8651	1	20.2	-42 1	5.3	+0.7	2	.012	162	114038	13	2.7	-10 12	5.3	+0.3	2	.010
6	9362	1	27.0	-49 35	4.0	+0.9	3	.024	163	114474	13	5.6	-42 50	5.3	+0.6	2	.011
143	9377	1	27.1	-30 48	5.8	+0.4	2	.008	164	115310	13	11.3	-30 59	5.4	+0.6	2	.011
7	11977	1	52.4	-68 9	4.7	+1.3	2	.021	165	117789	13	27.5	-14 51	5.6	+0.3	2	.008
144	13940	2	10.5	-41 38	5.9	+0.5	2	.008	166	119834	13	40.4	-50 56	4.7	+0.4	4	.014
145	15975	2	28.9	-35 5	5.9	+0.3	2	.008	167	121474	13	50.4	-63 11	4.7	+0.5	2	.015
8	16815	2	36.7	-40 17	4.1	+1.3	4	.028	36	123123	14	0.7	-26 12	3.5	+1.1	2	.033
9	17652	2	44.9	-32 50	4.5	+1.9	2	.030	37	123139	14	0.8	-35 53	2.3	+1.1	4	.059
10	17824	2	46.5	-21 25	4.8	+0.6	2	.014	168	123569	14	3.3	-52 57	4.8	+1.1	2	.018
13	22663	3	33.5	-40 36	4.6	+0.7	2	.017	169	124206	14	7.0	-26 47	5.2	+1.1	2	.015
15	23817	3	42.9	-65 7	3.8	+0.6	2	.023	170	128266	14	30.8	-45 42	5.4	+0.3	2	.009
16	24160	3	45.7	-36 30	4.2	+0.3	2	.016	171	131342	14	47.9	-59 42	5.2	+0.7	2	.012
17	26967	4	10.7	-42 32	3.8	+1.6	3	.036	172	133340	14	58.8	-40 41	5.3	+0.2	3	.010
146	29085	4	29.6	-29 57	4.6	+2.4	2	.036	173	133774	15	1.1	-15 52	5.3	+1.5	2	.018
147	29291	4	31.7	-30 46	3.9	+0.1	3	.018	39	135758	15	11.7	-29 47	4.4	-0.3	2	.011
19	32831	5	0.8	-35 37	4.6	+0.8	2	.017	174	139663	15	34.3	-23 30	5.1	-0.2	2	.009
20	34642	5	13.9	-35 0	4.9	+2.4	3	.031	175	147675	16	18.1	-78 40	3.9	+0.4	2	.020
21	34649	5	13.9	-67 18	4.8	+0.3	2	.013	176	148786	16	25.4	-16 23	4.4	-0.3	2	.011
22	36597	5	27.7	-35 33	3.9	0.0	2	.016	177	148890	16	26.1	-65 17	5.4	+1.1	2	.014
148	37811	5	36.1	-32 41	5.5	-0.1	2	.007	178	151680	16	43.7	-34 7	2.4	+0.7	2	.047
23	39364	5	47.0	-20 53	3.9	+4.5	2	.132	179	153687	16	55.8	-4 4	5.0	+1.1	2	.017
24	39425	5	47.4	-35 48	3.2	+0.1	2	.024	98	156266	17	11.5	-0 20	4.8	+1.1	2	.018
25	39523	5	48.0	-56 12	4.4	+0.7	2	.018	180	159433	17	29.6	-38 34	4.3	+0.8	2	.020
149	40176	5	52.1	-37 8	5.0	-0.3	2	.009	181	160635	17	35.9	-64 41	3.6	-0.2	2	.018
150	40409	5	53.4	-63 8	4.5	+1.1	2	.021	182	165135	17	59.4	-30 26	3.1	+1.1	2	.040
26	40808	5	56.1	-42 49	4.0	-0.1	3	.015	183	166063	18	3.8	-45 58	4.6	-0.2	3	.011
27	43785	6	13.0	-35 6	4.5	0.0	2	.013	41	168454	18	14.6	-29 52	2.8	-0.1	3	.026
28	50310	6	47.5	-50 30	2.8	0.0	3	.027	184	169420	18	19.4	-20 35	5.0	+0.4	3	.012
29	55865	7	9.6	-70 20	3.9	+1.1	2	.028	185	169767	18	21.1	-49 7	4.1	+0.9	3	.022
30	63295	7	43.0	-72 22	3.9	+1.2	2	.029	186	169836	18	21.4	-57 35	5.8	+1.5	2	.014
31	69142	8	10.5	-40 2	4.4	+0.3	2	.015	42	169916	18	21.8	-25 29	2.9	+1.1	4	.043
32	71701	8	23.6	-77 10	4.3	+0.2	2	.015	187	171443	18	29.8	-8 19	4.1	+0.6	2	.020
151	78004	9	0.7	-46 42	3.7	+0.4	2	.022	188	171759	18	31.4	-71 31	4.1	+1.8	2	.035
152	79917	9	11.7	-38 9	5.0	+0.7	2	.014	189	175190	18	49.1	-22 47	5.0	-0.1	4	.009
153	81799	9	22.7	-21 54	4.9	+1.1	2	.017	43	175775	18	51.8	-21 14	3.6	+0.3	4	.022
154	87783	10	2.2	-46 53	5.2	+1.1	2	.015	190	177389	18	59.3	-68 35	5.3	+1.8	2	.020

No.	H.D.	R.A. 1900	Dec. 1900	Vis. Mag.	Abs. Mag.	Rel. Wt.	π	No.	H.D.	R.A. 1900	Dec. 1900	Vis. Mag.	Abs. Mag.	Rel. Wt.	π
		<i>h m</i>	<i>o /</i>				<i>"</i>			<i>h m</i>	<i>o /</i>				<i>"</i>
45	177716	19 0.7	-27 49	3.4	+0.7	2	.029	205		21 53.2	-38 52	5.6	0.0	3	.008
191	177873	19 1.3	-40 39	4.7	+1.0	3	.019	206		22 11.4	-13 20	5.6	+0.4	2	.009
192	182629	19 20.4	-21 58	5.6	+1.1	2	.013	207		22 37.7	-41 56	4.9	+0.6	2	.014
193	184127	19 27.8	-48 19	5.0	-0.2	2	.009	208		22 39.5	-54 1	4.9	+1.8	4	.024
117	185644	19 35.0	-16 31	5.4	+1.1	2	.013	209		22 50.4	-33 1	4.3	+1.1	4	.023
47	186648	19 40.5	-20 0	5.1	+0.5	2	.012	210		22 58.4	-42 1	5.8	+0.3	2	.008
194	188114	19 48.4	-42 8	4.2	+0.7	2	.020	50		23 4.1	-21 43	3.8	+0.6	3	.023
195	195569	20 27.0	-44 51	5.3	+0.4	2	.010	211		23 4.7	-45 47	4.1	+0.2	4	.017
196	196171	20 30.5	-47 38	3.2	+0.5	4	.029	212		23 11.1	-45 2	5.9	+1.2	2	.012
197	198232	20 43.8	-34 9	5.0	+0.3	3	.011	213		23 13.4	-33 5	4.5	+0.4	3	.015
198	198357	20 44.6	-38 17	5.6	+0.2	2	.009	214		23 17.7	-20 39	4.2	+1.2	2	.025
199	198700	20 47.0	-58 50	3.7	0.0	4	.018	215		23 19.6	-57 24	5.6	+0.8	3	.011
200	203638	21 18.4	-21 16	5.5	+0.8	2	.012	216		23 21.5	-59 2	5.6	+0.8	2	.011
201		21 25.8	-41 38	5.4	+0.6	3	.011	217		23 52.1	-82 44	5.7	+0.2	2	.008
202		21 26.9	-45 18	5.7	+0.9	2	.011	218		23 53.7	-53 19	5.1	+1.1	3	.016
203		21 30.4	-77 50	3.7	+1.2	4	.031	219		23 55.9	-49 22	5.7	+0.3	2	.008
204		21 36.4	-23 43	5.3	+0.6	2	.011								

Since only a few good trigonometric parallaxes of southern stars of Class K0 are now available, the relation of line intensity to absolute magnitude has been calibrated by means of the proper motions in the Preliminary General Catalogue of Boss. The considerable dispersion about the mean value is clearly shown in Harvard Bulletin 788 by the tabulations of mean intensities and proper motions (reduced to apparent magnitude 5.0). The dispersion cannot be determined numerically with high confidence, however, because of its complication with the well known, but uncertainly evaluated, increase of space velocity with decreasing absolute brightness. That is, large proper motions may result from nearness to the observer, which indicates faint absolute magnitude, and from the greater real velocity in space that is associated with the low luminosity.

For the disentangling of the two effects, we have adopted the tentative formula, recently deduced by Eddington and Douglas, for the relation of velocity to absolute magnitude (M.N. **83**, 112, 1923). The conspicuous run in reduced proper motion with line intensity is thus attributed partly to the effect of distance, and partly to the change of speed with absolute brightness.

Table II contains the absolute magnitudes and parallaxes for 121 giant stars for which the photographs are satisfactory in quantity and quality. The few dwarfs and c-stars encountered in this work are not included, because they are insufficiently numerous to permit the determination of mean magnitudes with certainty. In the first column is the Harvard parallax number, continued from

Harvard Circulars 228 and 232. Since the present observations have been made independently of earlier work, and the absolute magnitudes are not based on the Mount Wilson system as previously, many stars are included here that have already appeared in the earlier lists. Such stars retain their original numbers. The second column contains the number of the star in the Henry Draper Catalogue, as far as they are now available (0^h to $21^h.4$).

The parallaxes of the 112 stars in Table III are less accurately determined than those of Table II. In the course of a few years it will be possible to give revised values based on new photographs. The mean apparent magnitude is 4.6 for the stars in Table II and 5.6 for the stars in Table III.

It is frequently believed that the parallax system of Mount Wilson Contribution 199 makes the giant K stars, on the average, somewhat too faint intrinsically. This conclusion is supported by the present investigation. The following tabulation indicates that the K0 giants are now classified about four-tenths of a magnitude brighter than on the earlier spectroscopic system.

		Systematic Difference <i>M</i>	Average Difference <i>M</i>	Number
Mt. W. 199	— H.C. 243	+0.53	± 0.51	23
H.C. 228,232	— H.C. 243	+0.39	± 0.46	43

The average differences above were computed after the mean systematic difference had been applied to the individual values of the absolute magnitudes. In

TABLE III
PARALLAXES AND ABSOLUTE MAGNITUDES FOR 112 SOUTHERN STARS OF CLASS K

No.	H.D.	R.A. 1900		Dec. 1900		Vis. Mag.	Abs. Mag.	π	No.	H.D.	R.A. 1900		Dec. 1900		Vis. Mag.	Abs. Mag.	π
		<i>h</i>	<i>m</i>	<i>o</i>	<i>i</i>			"			<i>h</i>	<i>m</i>	<i>o</i>	<i>i</i>			"
220	720	0	6.4	—28	21	5.6	+0.6	.010	236	38871	5	43.7	—46	38	5.1	+0.1	.010
221	1187	0	11.1	—32	0	5.7	+0.1	.012	237	43899	6	13.6	—37	42	5.6	+0.3	.009
222	3059	0	28.7	—30	7	5.6	+0.3	.009	238	52703	6	57.1	—33	20	6.5	+1.1	.008
223	4737	0	44.3	—47	15	6.2	+0.3	.006	239	59219	7	23.8	—50	49	5.1	+0.1	.010
224	5457	0	51.2	—70	4	5.3	+0.3	.010	240	60666	7	30.5	—26	48	5.8	+0.3	.008
225	6793	1	3.4	—62	19	5.3	+1.9	.021	241	63744	7	45.3	—46	50	4.6	+1.1	.020
226	9349	1	26.9	—30	30	6.8	+1.1	.007	242	64572	7	49.4	—36	6	5.5	—0.3	.007
227	9525	1	28.4	—37	22	5.5	+0.3	.009	243	69123	8	10.4	—35	11	5.8	+0.3	.008
228	10537	1	37.6	—32	49	5.3	+1.1	.015	244	71878	8	24.6	—65	48	3.6	+0.6	.025
229	11050	1	43.4	—37	39	6.4	—0.3	.005	245	80170	9	13.1	—38	59	5.4	+0.3	.010
230	13336	2	5.2	—43	59	5.8	+1.1	.012	246	83380	9	32.9	—31	44	5.6	+0.3	.009
231	14728	2	17.4	—18	7	6.0	+0.5	.008	247	83548	9	34.1	—42	45	5.5	—0.6	.006
232	19141	2	59.6	—47	22	5.7	+2.0	.019	248	84152	9	37.9	—56	48	5.8	+0.6	.009
233	27588	4	16.1	—44	30	5.1	+1.1	.016	249	85396	9	46.3	—76	19	5.4	+1.6	.018
234	28093	4	20.8	—63	37	5.2	+1.1	.015	250	94776	10	51.3	—59	59	6.8	+0.6	.006
235	36134	5	24.4	—3	32	6.1	+0.5	.008	251	96566	11	2.4	—61	53	4.8	+0.3	.013

No.	H.D.	R.A. 1900		Dec. 1900		Vis. Mag.	Abs. Mag.	π	No.	H.D.	R.A. 1900		Dec. 1900		Vis. Mag.	Abs. Mag.	π
		<i>h</i>	<i>m</i>	<i>o</i>	<i>t</i>			"			<i>h</i>	<i>m</i>	<i>o</i>	<i>t</i>			"
252	100708	11	30.2	-48	35	5.6	+1.6	.016	291	165687	18	2.1	-17	10	5.7	+1.1	.012
253	105340	12	2.6	-74	48	5.2	+0.6	.012	292	166023	18	3.6	-30	45	5.6	+0.4	.009
254	106321	12	8.8	-45	10	5.3	+1.6	.018	293	173791	18	42.0	-45	55	5.8	+2.4	.021
255	107567	12	16.6	-67	45	5.8	+0.6	.009	294	174116	18	43.8	-20	26	5.4	+0.5	.011
256	108570	12	23.2	-55	50	6.2	+2.4	.017	295	174295	18	44.7	-52	13	5.3	+1.3	.016
257	109960	12	33.7	-29	52	6.0	+1.4	.012	113	176678	18	56.3	-5	53	4.2	+1.1	.025
258	111315	12	43.3	-71	26	5.6	-0.2	.007	44	177241	18	58.7	-21	53	3.9	0.0	.017
259	114149	13	3.6	-22	35	5.1	-0.3	.008	296	179799	19	8.8	-8	54	6.5	+0.6	.006
260	114971	13	8.9	-48	25	6.0	+2.0	.016	297	180540	19	11.8	-19	8	5.0	-0.3	.009
261	120913	13	47.2	-67	10	5.7	-0.1	.007	298	182477	19	19.7	-14	6	5.8	+1.6	.014
262	121416	13	50.1	-46	6	5.9	0.0	.007	299	184835	19	31.2	-18	28	5.9	+1.1	.011
263	121853	13	52.9	-49	53	6.1	+0.8	.009	300	188584	19	50.7	-67	13	5.7	+1.1	.012
264	122430	13	56.7	-26	57	5.7	+1.1	.012	301	188887	19	52.2	-67	13	5.2	+0.3	.011
265	124147	14	6.6	-53	12	5.5	+0.3	.009	302	190056	19	58.0	-32	20	5.0	+1.4	.019
266	124281	14	7.5	-26	8	6.3	-0.3	.005	303	190664	20	0.9	-4	22	6.6	-0.3	.004
89	124294	14	7.6	-9	48	4.3	+1.6	.029	122	193150	20	13.6	-19	26	5.5	+0.6	.011
267	126218	14	19.1	-24	21	5.4	-0.3	.007	304	194215	20	19.3	-28	59	6.0	+0.3	.007
268	127501	14	26.6	-52	14	5.9	+1.1	.011	305	197635	20	39.8	-69	9	5.5	-0.1	.008
269	131430	14	48.5	-24	14	5.4	+0.6	.011	306	198308	20	44.3	-51	59	5.2	-0.3	.008
270	131530	14	49.0	-11	29	5.8	+0.3	.008	307	200073	20	56.0	-38	55	5.9	+1.9	.016
271	131918	14	51.3	-11	0	5.6	+0.8	.011	308	200702	20	59.9	-41	47	5.6	+0.6	.010
272	132345	14	53.5	-10	44	6.0	+0.1	.007	309	201852	21	7.1	-36	50	6.1	+0.3	.007
273	134505	15	5.1	-51	43	3.5	-0.3	.017	310	202320	21	9.9	-21	4	5.4	+0.3	.010
274	137709	15	22.4	-46	23	5.0	+1.1	.016	311	203949	21	20.2	-38	16	5.7	+0.5	.009
275	138137	15	25.0	-16	16	5.9	-0.3	.006	312	204139	21	21.5	-21	37	6.0	+1.9	.015
276	138538	15	27.6	-65	59	4.1	+1.3	.027	313		21	38.7	-49	57	6.5	+0.8	.007
277	139329	15	32.4	-20	41	5.9	+0.3	.007	314		21	43.5	-48	11	6.6	+0.3	.005
278	139521	15	33.5	-34	5	4.6	+0.9	.018	315		21	48.9	-4	45	5.9	+0.4	.008
279	143346	15	54.7	-72	7	5.7	+0.3	.008	316		21	59.9	-44	27	7.0	+1.4	.008
280	143787	15	57.3	-25	36	5.1	+1.1	.016	317		22	13.6	-13	48	6.1	+1.6	.013
281	145397	16	5.6	-54	22	5.1	+0.6	.013	318		22	17.9	-25	16	5.6	-0.1	.007
282	147700	16	18.3	-19	49	4.6	+0.1	.013	319		22	22.8	-39	38	5.5	+0.2	.009
283	148291	16	21.9	-61	25	5.1	-0.1	.009	320		22	36.9	-44	16	6.3	+2.4	.017
284	150259	16	34.7	-20	13	6.5	+1.1	.008	321		22	55.9	-29	23	5.7	+0.6	.009
285	150416	16	35.8	-17	33	5.0	-0.6	.007	322		23	2.9	-29	22	5.8	+2.0	.017
286	151078	16	40.0	-39	12	5.5	+0.3	.009	323		23	9.4	-41	39	5.8	+0.7	.010
287	157457	17	18.2	-50	33	5.2	-0.3	.008	324		23	26.0	-45	24	5.9	+2.0	.016
288	161814	17	42.5	-60	8	5.8	0.0	.007	325		23	35.4	-32	38	5.3	+0.5	.011
289	163532	17	51.5	-4	4	5.6	+0.6	.010	326		23	38.6	-79	21	5.7	+0.6	.010
290	164870	17	58.1	-35	54	5.8	+0.3	.008	327		23	59.2	-17	5	5.8	+0.3	.008

comparing with Mount Wilson, the discordant star δ Leporis (H.D. 39364) has been omitted. (Cf. Harvard Circular 228 and Table II of Harvard Circular 232.) By far the largest outstanding disagreement with the former work is 2.1 magnitudes for λ Sagittarii (H.D. 169916); the previous accordance of the Harvard and

Mount Wilson values was largely the result of using the star for fixing a point on the curve of calibration.

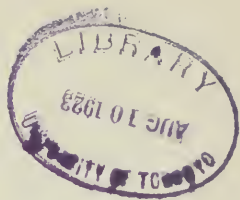
The mean absolute magnitude of the 233 stars in Tables II and III is $+0.67$, in agreement with an unpublished mean value recently derived by Luyten from the trigonometric parallaxes of northern K0 stars, and also agreeing closely with the mean that may be obtained from the parallactic and peculiar motions of bright K0 stars for the whole sky.

In comparing the parallaxes deduced from proper motions or trigonometric measures with spectroscopic parallaxes, which depend for giant red stars so largely on the strontium line 4215, it is well to remember that the intensity of the spectral line is actually a direct indicator of ionization conditions, and only indirectly an index of total luminosity. Any irregularities in the behavior of ionized strontium in stellar atmospheres would invalidate the spectroscopic parallaxes. For instance, the McCormick parallax of δ Leporis makes it a normal giant star, but the numerous Harvard spectrograms show conclusively that the star is either of faint absolute brightness, as the proper motion seems to indicate (H.C. 228), or that the enhanced lines of strontium are peculiar for that particular star.

MAY 25, 1923

HARVARD COLLEGE OBSERVATORY

CIRCULAR 244



OBSERVED MAXIMA AND MINIMA OF VARIABLE STARS FOR 1922

BY LEON CAMPBELL

As announced in Harvard Circular 235, it is planned to publish annually the observed dates of maxima and minima for the extensive list of long period variables which have been continuously observed by the members of the variable star associations, and other individuals, who send their results monthly to the Harvard Observatory. Such a list places promptly in the hands of astronomers the preliminary results derived from these observations. It also serves to indicate the stars whose periods appear to be more or less irregular.

While the data here given can be considered as fairly reliable, it is to be noted that subsequent observational material may alter the dates of maxima and minima to some extent. Such revisions are indicated, for a few of the determinations published last year, in the remarks at the end of the table. More detailed and definitive results are to appear in a forthcoming volume of the Harvard Annals.

The table contains the observed dates for 1922, arranged in the same form as those given in Harvard Circular 235. The system of weights is the same as previously used. The value of the interval gives one an approximate idea of the period of the star in question.

For this report maxima and minima have been determined for 376 variables distributed over the whole sky, for which the maximum brightness is generally of magnitude 9.0 or brighter, and the range is at least three magnitudes. There are 501 determinations of maxima and 508 determinations of minima.

A comparison of the predicted dates for 1922, published in Harvard Circular 227, with the observed values here given, yields the following results. The average difference for 446 maxima common to both lists is ± 12.9 days, and for the 448 minima, ± 15.1 days. Expressed in percentages, 29 per cent of the determinations are within 5 days of the predicted dates, 49 per cent are within 10 days, and 85 per cent differ less than 25 days. These deviations from prediction are of about the same order as those for 1921.

OBSERVED MAXIMA AND MINIMA

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
000339	V Scl	..	242	..	d	..	242	2	d	013238	RU And	10.2	242	5	d	..	242	..	d
001032	S Scl	6.9	3404	5	367	12.4	3252	3	377	013338	Y And	9.1	3226	3	226	..	3117	2	225
001046	X And	9.0	3360	5	337	14.5	3236	4	346	"	"	9.5	3444	4	218	14.5	3338	5	221
001726	T And	8.7	3304	5	281	..	3181	2	283	014958	X Cas	10.2	3154	5	447	12.3	3328	5	446
001755	T Cas	7.4	3233	5	463	..	..	..	..	015354	U Per	7.9	3112	4	322	10.0	3295	5	330
001838	R And	7.3	3070	5	389	14.7	3346	5	431	"	"	8.0	3440	4	328	..	..	..	..
001862	S Tuc	..	3143	2	244	..	3271	3	231	015912	S Ari	11.2	3266	3	292	..	3120	2	282
"	"	8.3	3368	5	225	..	..	..	..	"	"	..	..	..	..	..	3407	3	287
001909	S Cet	8.3	3088	3	310	..	3249	2	305	021024	R Ari	..	3178	3	188	12.5	3089	5	181
"	"	7.8	3408	5	320	..	..	..	..	"	"	8.0	3367	5	189	13.2	3276	4	187
002438a	T Scl	..	3372	4	..	..	3287	3	..	021143a	W And	7.0	3332	5	390	13.3	3168	4	390
002546	T Phe	9.8	3069	4	277	..	3220	2	278	021281	Z Cep	10.4	3172	3	276	15.5	3328	5	281
"	"	9.3	3349	5	280	..	..	..	..	021403	o Cet	..	3172	3	350	8.6	3356	5	304
003179	Y Cep	10.5	3144	5	318	14.5	3344	5	329	021558	S Per	..	..	..	..	11.0	3400	..	..
004047	U Cas	8.6	3287	5	277	..	3162	3	298	022000	R Cet	8.1	3358	4	..	..	3123	2	169
004132	RW And	8.9	3277	4	424	..	3128	3	404	022150	RR Per	8.6	3108	5	385	14.5	3333	5	408
004435	V And	..	3168	2	256	14.5	3302	3	250	022426	R For	..	3334	3	424	12.5	3115	3	392
"	"	9.0	3416	4	248	..	..	..	..	022813	U Cet	7.5	3126	3	232	12.8	3261	3	236
004435	X Scl	..	3111	3	259	..	3255	3	265	"	"	7.3	3371	5	245	..	..	..	..
"	"	10.3	3376	5	265	..	..	..	..	022980	RR Cep	10.4	3234	5	390	14.5	3082	5	407
004533	RR And	8.6	3080	5	310	15.0	3248	3	328	023133	R Tri	6.8	3074	5	264	12.5	3234	3	268
"	"	9.4	3392	4	316	..	..	..	..	"	"	6.9	3346	5	272	..	..	..	..
004746a	RV Cas	9.3	3077	5	339	15.0	3289	5	332	024356	W Per	8.6	3146	5	498	10.7	3414	5	514
"	"	9.0	3409	4	332	..	..	..	..	025050	R Hor	6.5	3270	4	433	14.0	3111	4	446
004958	W Cas	8.4	3082	5	408	12.0	3306	5	407	025751	T Hor	8.0	3280	4	226	..	3164	2	211
005475	U Tuc	8.1	3287	5	267	..	3161	3	254	"	"	..	..	..	..	13.2	3385	5	221
010102	Z Cet	..	..	..	..	14.0	3071	4	181	030514	U Ari	..	3192	4	377	15.0	3378	5	360
"	"	8.9	3342	5	..	..	3254	2	183	031401	X Cet	8.6	3090	5	177	..	3194	2	181
010630	U Scl	9.0	3071	4	334	..	3302	3	330	"	"	8.9	3266	3	176	12.2	3368	5	174
"	"	9.8	3407	5	336	..	..	..	..	032043	Y Per	8.3	3254	5	230	9.9	3148	4	264
010940	U And	9.6	3211	5	328	14.0	3058	5	330	"	"	..	..	..	..	10.0	3364	5	216
"	"	..	..	..	..	14.5	3410	4	352	032335	R Per	8.7	3108	5	213	..	3206	3	202
011041	UZ And	..	3142	3	279	14.7	3028	3	274	"	"	8.3	3308	5	200	..	..	..	..
"	"	..	..	..	..	15.2	3347	4	319	035124	T Eri	..	3156	1	233	..	3277	3	..
011208	S Psc	10.0	3308	3	394	..	3137	2	363	042209	R Tau	8.6	3285	3	331	..	3138	3	310
011272	S Cas	..	..	..	..	15.2	3404	4	644	042215	W Tau	9.2	3324	4	272	..	3194	3	298
011712	U Psc	..	3154	1	178	..	3066	2	194	042309	S Tau	..	3262	2	402	..	..	..	..
"	"	10.5	3326	5	172	..	3224	2	158	043065	T Cam	7.8	3212	5	370	13.8	3418	4	368
"	"	..	..	..	..	..	3400	3	176	043208	RX Tau	..	3212	3	334	14.0	3062	4	345
012350	RZ Per	..	3138	4	346	13.8	3358	4	346	"	"	..	..	..	..	14.0	3394	5	332
012502	R Psc	..	3218	3	350	..	3048	3	320	043263	R Ret	7.2	3317	5	277	..	3198	3	270
"	"	..	..	..	..	14.8	3414	3	366	043274	X Cam	8.2	3088	5	144	12.6	3164	5	150
013238	RU And	10.3	3128	4	226	13.5	3247	3	237	"	"	8.1	3232	5	144	12.5	3306	5	142

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
			242				242		<i>d</i>				242		<i>d</i>		242		<i>d</i>
043274	X Cam	8.0	3370	5	138	..	..	..	..	061702	V Mon	..	..	..	..	12.8	3382	4	330
043562	R Dor	7.0	3270	4	351	6.1	3140	4	392	063159	U Lyn	9.5	3334	4	424	14.5	3153	4	425
"	"	..	..	..	..	6.0	3363	5	223	063558	S Lyn	..	3278	4	308	14.5	3132	4	284
043738	R Cae	8.4	3070	4	379	13.5	3326	3	388	064030	X Gem	8.2	3182	4	261	13.2	3050	5	266
044617	V Tau	9.7	3065	4	175	13.3	3136	4	158	"	"	..	..	..	..	..	3312	3	262
"	"	..	3223	3	158	13.9	3314	5	178	065111	Y Mon	9.2	3108	5	218	..	3228	3	220
"	"	9.8	3402	5	179	..	..	..	..	"	"	8.8	3340	4	232	..	..	..	..
045307	R Ori	9.3	3270	3	396	13.0	3107	4	393	065208	X Mon	7.2	3000	4	151	..	2921	2	161
045514	R Lep	7.5	3300	4	428	..	..	..	..	"	"	7.6	3151	4	151	9.2	3071	4	150
050003	V Ori	9.0	3066	5	273	..	3202	3	279	"	"	..	3292	2	141	..	3219	2	148
"	"	9.5	3341	4	275	..	..	..	..	"	"	..	..	..	..	8.9	3364	3	145
050022	T Lep	8.0	3086	5	363	..	3284	4	360	065355	R Lyn	7.6	3229	5	381	13.8	3420	5	378
050548	S Pic	8.2	3357	4	403	..	3212	3	422	070109	V CMi	9.1	3346	4	371	..	3200	3	353
050953	R Aur	7.4	3399	5	466	..	3142	5	447	070122a	R Gem	6.5	3355	5	351	..	3251	3	391
051247	T Pic	..	3233	3	201	..	3142	3	191	070310	R CMi	8.2	3100	5	369	11.5	3271	3	352
"	"	..	..	..	..	..	3346	3	204	070772	R Vol	9.1	3254	5	462	..	..	..	..
051533	T Col	7.5	3222	2	224	12.4	3108	3	217	071201	RR Mon	..	3327	3	405	..	3181	2	431
"	"	..	..	..	..	12.3	3329	4	221	071713	V Gem	..	3202	4	294	14.2	3071	4	272
052034	S Aur	..	..	..	..	10.0	3118	5	588	"	"	..	..	..	..	13.9	3349	4	278
052036	W Aur	9.1	3162	5	269	14.0	3060	5	290	072708	S CMi	7.5	3218	3	346	13.0	3383	5	341
"	"	..	..	..	..	15.0	3334	4	274	072811	T CMi	9.4	3097	5	332	..	3282	3	316
052404	S Ori	7.8	3322	5	432	13.2	3116	5	427	"	"	9.5	3411	5	314	..	..	..	..
053068	S Cam	8.5	3398	5	350	10.8	3226	5	325	072820b	Z Pup	..	3231	3	506	..	3047	2	495
053531	U Aur	8.7	3193	4	418	14.5	3444	5	414	073173	S Vol	8.9	3391	5	391	13.7	3193	3	393
054331	S Col	..	3282	3	305	..	3139	3	322	073508	U CMi	8.6	3356	4	403	12.7	3182	3	406
054615a	Z Tau	..	3142	3	538	13.5	3418	3	518	073723	S Gem	9.3	3071	5	292	..	3239	3	289
054629	R Col	9.0	3323	3	323	..	3202	3	342	"	"	8.3	3358	5	287	..	..	..	..
054920	U Ori	6.3	3280	4	392	12.2	3144	4	381	074241	W Pup	..	3154	3	111	12.3	3102	3	120
054974	V Cam	..	..	..	..	[15	3330	4	521	"	"	..	3287	4	133	12.6	3226	4	124
055353	Z Aur	9.4	3151	5	118	11.0	3095	5	116	"	"	8.0	3401	5	114	12.1	3347	4	121
"	"	9.3	3261	4	110	10.9	3207	5	112	074323	T Gem	8.6	3094	5	286	..	3242	3	273
"	"	9.3	3374	5	113	10.9	3319	5	112	"	"	8.3	3363	5	269	..	..	..	..
055686	R Oct	9.1	3350	5	406	..	3169	3	419	074922	U Gem	9.6	3071	3	81	14.0	3123	4	88
060450	X Aur	8.6	3130	5	154	..	3212	3	165	"	"	9.3	3174	5	103	14.0	3411	5	..
"	"	8.4	3288	5	158	12.6	3364	4	152	"	"	9.3	3346	3	..	..	..	..	..
060547	SS Aur	10.9	3079	5	48	..	3058	3	53	081112	R Cnc	6.5	3135	5	354	11.5	3312	4	352
"	"	10.8	3122	5	43	..	3102	3	44	081617	V Cnc	7.4	3080	5	264	..	3222	3	271
"	"	11.0	3173	3	51	15.0	3153	3	51	"	"	8.0	3351	4	271	..	..	..	..
"	"	10.9	3237	3	64	..	3204	2	51	082476	R Cha	8.6	3303	5	342	..	3179	3	372
"	"	11.2	3289	4	52	..	3267	3	63	083019	U Cnc	..	3248	2	316	14.0	3126	4	297
"	"	11.0	3325	3	36	15.4	3310	4	43	083350	X UMa	..	3286	3	256	14.0	3184	3	253
"	"	10.7	3370	4	45	..	3348	3	38	084803	S Hya	8.0	3172	5	266	..	3300	3	263
"	"	11.5	3404	5	34	..	3391	4	43	085008	T Hya	7.4	3171	4	293	..	3322	3	294
061647	V Aur	..	3324	3	380	12.6	3118	4	337	085120	T Cnc	8.5	3229	4	483	..	3000	3	474
061702	V Mon	..	3219	2	339	..	3052	3	330	090024	S Pyx	8.5	3139	4	222	..	3241	3	211

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
			242		<i>d</i>		242		<i>d</i>				242		<i>d</i>		242		<i>d</i>
090024	S Pyx	..	3342	3	203	..	..	..	..	123160	T UMa	7.8	3308	5	248	..	..	..	..
090425	W Cnc	8.2	3420	4	389	14.4	3268	4	387	123307	R Vir	6.5	3066	5	145	11.4	3141	5	151
091868	RW Car	9.0	3337	5	318	..	3187	3	303	" "	" "	6.1	3221	5	155	..	3280	3	139
092551	Y Vel	..	..	..	..	13.7	3288	4	438	" "	" "	6.5	3369	4	148	..	..	..	..
092962	R Car	4.4	3187	4	319	9.6	3348	5	310	123459	RS UMa	8.6	3198	5	258	14.3	3082	5	255
093014	X Hya	..	3333	3	319	..	3208	3	300	" "	" "	..	..	..	..	14.2	3351	4	269
093178	Y Dra	8.2	3299	5	317	14.3	3144	5	306	123961	S UMa	7.4	3123	5	226	12.0	3246	5	228
093934	R LMi	7.2	3120	5	371	12.4	3340	5	367	" "	" "	7.4	3352	5	229	..	..	..	..
094023	RR Hya	..	3377	4	..	..	3202	2	350	124204	RU Vir	..	3354	2	..	13.8	3165	3	385
094211	R Leo	5.8	3334	4	307	10.1	3190	5	307	124606	U Vir	8.4	3239	4	203	12.8	3148	4	190
094953	Z Vel	9.0	3294	4	433	[14	3183	3	424	" "	" "	..	..	..	..	..	3354	2	206
095421	V Leo	..	3310	3	284	13.6	3178	4	272	130212	RV Vir	..	3014	1	253	15.0	3180	3	256
095458	RR Car	7.9	3217	4	..	..	3142	3	..	131283	U Oct	..	3135	4	315	13.2	3294	4	296
"	"	7.8	3363	4	146	8.8	3304	4	162	132202	V Vir	..	3223	2	..	14.5	3132	3	234
095563	RV Car	..	..	..	..	..	3374	2	..	" "	" "	..	..	..	..	..	3377	2	245
100661	S Car	5.8	3100	3	138	9.9	3190	4	157	132422	R Hya	..	..	..	..	9.8	3261	3	425
"	" "	6.0	3266	5	166	..	3336	4	146	132706	S Vir	7.6	3111	5	378	..	3319	3	392
"	" "	5.4	3396	5	130	..	..	..	..	133155	RV Cen	7.0	3143	4	431	9.5	3368	5	457
101058	Z Car	..	3323	4	380	..	3167	2	367	133273	T UMi	9.2	3284	5	316	13.6	3150	5	325
101153	W Vel	9.3	3281	5	391	..	3139	3	418	133633	T Cen	..	3149	3	97	8.6	3110	3	94
103270	RZ Car	..	3225	4	274	..	3386	3	..	" "	" "	6.0	3239	4	90	8.4	3203	5	93
103769	R UMa	7.6	3270	5	307	13.1	3140	5	307	" "	" "	..	3337	3	98	..	3294	3	91
104620	V Hya	..	..	..	..	9.8	3260	4	530	" "	" "	5.9	3416	4	79	..	3388	2	94
104628	RS Hya	..	3309	3	336	..	3153	3	309	134236	RT Cen	9.3	3186	4	248	11.9	3071	3	257
104814	W Leo	9.1	3107	4	389	14.0	3369	4	389	" "	" "	..	..	..	..	12.3	3320	4	249
110506	S Leo	10.3	3113	4	..	..	3196	2	188	134440	R CVn	7.5	3151	5	323	12.4	3332	4	332
"	" "	..	3301	1	188	..	3395	3	199	134536	RX Cen	9.7	3074	3	326	..	3275	2	315
111661	RS Cen	9.1	3060	3	149	..	3139	1	155	" "	" "	9.2	3386	4	312	..	..	..	..
"	" "	..	3214	3	154	..	3328	3	189	134677	T Aps	..	3100	3	272	..	3260	2	267
"	" "	8.5	3389	5	175	..	..	..	..	" "	" "	10.0	3366	5	266	..	..	..	..
114441	X Cen	7.0	3098	4	323	13.2	3290	4	330	135908	RR Vir	11.6	3136	4	210	..	3268	3	218
"	" "	7.2	3400	4	302	..	..	..	..	" "	" "	..	3366	3	230	..	..	..	..
115058	W Cen	8.1	3255	5	207	..	3152	2	187	140113	Z Boo	9.0	3112	4	284	15.0	3286	4	282
"	" "	..	..	..	..	..	3358	3	206	" "	" "	..	3394	3	282	..	..	..	..
115919	R Com	8.7	3220	5	360	14.5	3093	5	361	140512	Z Vir	10.0	3224	4	286	15.0	3133	3	300
120012	SU Vir	8.6	3107	2	210	..	3228	3	..	140528	RU Hya	9.6	3224	5	337	14.5	3074	2	337
"	" "	..	3298	1	191	..	..	..	..	140959	R Cen	5.8	3180	4	559	8.4	3072	4	570
120905	T Vir	..	3272	3	321	14.2	3161	5	372	" "	" "	..	..	..	..	11.5	3385	5	538
121418	R Crv	7.5	3157	5	319	..	3333	3	295	141567	U UMi	7.6	3161	5	325	12.3	3350	5	344
122001	SS Vir	6.0	3353	3	355	9.3	3188	4	370	141954	S Boo	8.1	3258	5	278	12.9	3126	5	273
122532	T CVn	9.3	3308	5	298	11.7	3172	5	280	" "	" "	..	..	..	..	13.1	3409	5	283
122803	Y Vir	9.5	3099	5	215	14.5	3214	3	211	142205	RS Vir	7.6	3138	5	345	..	3380	3	360
122854	U Cen	8.3	3214	5	214	..	3116	3	233	142539	V Boo	7.0	3143	5	258	10.9	3282	5	252
"	" "	..	..	..	..	..	3330	3	214	" "	" "	7.5	3393	5	250	..	..	..	..
123160	T UMa	8.6	3060	5	267	13.1	3190	5	240	142584	R Cam	8.2	3202	5	269	12.3	3074	4	274

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Meg.	J. D.	Wt.	Int.	Meg.	J. D.	Wt.	Int.			Meg.	J. D.	Wt.	Int.	Meg.	J. D.	Wt.	Int.
142584	R Cam	..	242	..	d	..	242	..	d	155018	RR Lib	8.7	3258	5	289	14.4	3140	5	289
143227	R Boo	7.5	3057	4	231	12.3	3170	5	224	"	"	..	..	..	..	..	3417	3	277
"	"	7.0	3281	5	224	11.9	3393	4	223	155229	Z CrB	10.4	3191	5	248	..	3100	3	275
143417	V Lib	9.0	3126	3	249	..	3275	3	..	"	"	..	..	..	..	..	3333	3	233
"	"	..	3369	1	243	..	..	..	..	155823	RZ Sco	9.1	3160	4	..	..	3100	3	167
144918	U Boo	9.8	3106	4	204	12.5	3196	4	204	"	"	8.2	3320	5	160	12.2	3243	5	143
"	"	9.8	3313	4	207	..	3399	3	203	"	"	..	..	..	..	..	3403	3	160
145254	Y Lup	..	3052	3	396	..	3325	3	415	160021	Z Sco	..	3402	4	379	13.0	3240	5	347
150018	RT Lib	8.5	3126	4	260	..	3258	3	238	160118	R Her	9.2	3162	5	311	..	3351	3	313
"	"	..	3360	1	234	..	..	..	..	160210	U Ser	8.8	3293	5	243	13.3	3193	5	235
150519	T Lib	..	3265	3	232	15	3173	3	232	160221a	X Sco	10.6	3182	3	..	..	3071	1	211
"	"	..	..	..	..	..	3404	2	231	"	"	..	3406	2	224	..	3294	2	223
150605	Y Lib	7.6	3087	5	269	..	3250	4	263	160519	W Sco	12.2	3250	4	..	14.5	3159	3	..
"	"	..	3369	3	282	..	..	..	..	"	"	..	..	..	..	..	3366	1	207
151520	S Lib	8.4	3176	5	178	11.9	3076	4	179	160625	RU Her	..	..	..	..	13.8	3264	5	466
"	"	..	3362	2	186	..	3264	4	188	161122a	R Sco	10.4	3217	5	217	..	3134	3	241
151714	S Ser	8.3	3282	5	359	13.6	3133	5	350	"	"	..	..	..	..	..	3342	3	208
151731	S CrB	7.7	3060	5	356	13.0	3290	5	342	161122b	S Sco	10.9	3154	4	184	..	3066	1	182
"	"	6.8	3412	5	352	..	..	..	..	"	"	11.6	3334	4	180	15	3249	4	183
151822	RS Lib	7.7	3182	5	204	11.5	3089	4	220	"	"	..	..	..	..	..	3409	3	160
"	"	..	3398	3	216	11.6	3300	5	211	161138	W CrB	8.4	3215	5	245	13.0	3116	4	244
152714	RU Lib	8.4	3219	5	320	..	3093	3	332	"	"	..	..	..	..	13.4	3350	5	234
"	"	..	..	..	..	..	3389	3	296	161607	W Oph	9.6	3140	5	320	..	3334	3	324
152849	R Nor	7.8	3257	5	474	12.8	3151	4	484	162112	V Oph	8.0	3297	4	267	10.2	3186	4	336
"	"	7.3	3420	5	480	9.4	3343	5	483	162119	U Her	7.1	3079	5	407	13.2	3332	5	416
153030	X Lib	11.5	3162	4	..	..	3092	1	..	162319	Y Sco	11.4	3294	4	356	15	3149	3	355
"	"	..	3335	1	173	..	3268	2	176	162807	SS Her	9.4	3110	4	122	..	3158	4	104
153215	W Lib	..	3066	2	189	15.0	3166	4	192	"	"	9.3	3211	4	101	..	3264	4	106
"	"	..	3255	3	189	..	3370	2	204	"	"	9.2	3312	5	101	..	3376	3	112
153378	S UMi	8.3	3252	5	322	11.5	3070	5	304	162815	T Oph	9.6	3160	4	360	..	3380	3	362
"	"	..	..	..	..	11.6	3418	5	348	162816	S Oph	9.8	3106	4	236	..	3260	3	..
153620a	U Lib	..	3042	1	226	15.0	3158	4	226	"	"	..	3355	2	249	..	..	..	..
"	"	..	3266	3	224	..	3393	2	235	163137	W Her	8.2	3175	5	272	13.6	3324	5	279
153654	T Nor	7.1	3242	5	240	..	3133	3	224	163172	R UMi	9.3	3129	4	200	10.4	3050	4	196
"	"	..	..	..	..	..	3390	3	257	"	"	9.3	3280	4	151	10.3	3184	4	134
154428	R CrB	6.2	3029	5	129	6.5	3059	4	83	"	"	..	..	..	..	10.4	3380	4	196
"	"	6.2	3085	4	56	6.4	3147	3	88	163266	R Dra	7.8	3159	5	252	12.5	3057	5	249
"	"	6.1	3225	4	140	7.3	3270	5	123	"	"	7.7	3402	5	243	12.7	3280	5	223
"	"	6.2	3330	4	115	6.4	3400	4	130	164319	RR Oph	9.2	3299	5	299	..	3165	3	299
154536	X CrB	9.1	3200	5	243	13.5	3090	4	234	164715	S Her	7.1	3079	4	306	12.2	3243	5	315
"	"	..	..	..	..	13.5	3331	5	241	"	"	7.3	3370	5	291	..	..	..	..
154615	R Ser	6.7	3117	5	360	13.5	3333	4	365	164844	RS Sco	6.6	3279	5	319	12.0	3170	4	321
154639	V CrB	7.2	3366	5	362	10.1	3211	5	365	165030	RR Sco	..	3087	3	267	11.5	3240	5	271
154715	R Lib	10.0	3270	4	222	..	3177	3	259	"	"	5.0	3370	4	283	..	..	..	..
154736	R Lup	9.9	3165	4	243	..	3279	3	..	165202	SS Oph	8.8	3264	5	..	..	3176	3	176

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
165202	SS Oph	..	242	..	d	..	242	3	d	182224	SV Her	..	242	..	d	..	242	5	d
165631	RV Her	9.8	3179	5	201	15.0	3097	3	207	182306	T Ser	10.0	3111	3	339	15.5	3289	5	315
"	"	..	3395	4	216	15.5	3303	4	206	183149	SV Dra	9.0	3244	4	244	..	3133	4	243
165636	RT Sco	..	3118	3	445	..	3390	2	437	"	"	..	..	..	..	14.0	3390	4	257
170215	R Oph	7.5	3085	3	305	13.0	3249	4	309	183225	RZ Her	9.0	3103	4	329	15.5	3287	5	351
"	"	7.6	3390	4	305	..	..	..	..	183308	X Oph	6.5	3155	4	324	9.0	3300	5	326
170627	RT Her	..	3066	4	304	15.0	3220	5	284	184134	RY Lyr	9.8	3168	4	315	15.0	3365	5	318
"	"	8.6	3348	5	282	..	..	..	..	184205	R Sct	4.8	3070	3	81	5.6	3100	3	70
170833	RW Sco	..	3148	3	425	..	3406	3	398	"	"	5.0	3120	3	50	7.1	3159	4	59
171401	Z Oph	7.9	3064	5	348	12.4	3280	5	345	"	"	5.0	3250	5	130	7.0	3320	5	161
171723	RS Her	7.8	3179	5	217	12.4	3080	4	213	"	"	4.9	3363	5	113	6.0	3386	5	66
"	"	8.4	3398	4	219	12.5	3299	5	219	184243	RW Lyr	11.5	3382	5	497	15.6	3168	5	477
172486	S Oct	..	3118	3	255	13.3	3298	4	277	185032	RX Lyr	11.7	3229	5	253	..	3123	3	253
"	"	8.6	3388	5	270	..	..	..	..	"	"	..	..	..	..	..	3379	3	256
172809	RU Oph	9.1	3233	5	207	..	3136	4	210	185512	ST Sgr	..	3070	3	..	..	3308	2	404
"	"	..	..	..	..	13.8	3338	4	202	185634	Z Lyr	9.9	3313	5	300	14.8	3174	4	285
173543	RU Sco	8.7	3363	5	365	..	3156	3	346	185737	RT Lyr	9.7	3230	5	258	..	3120	3	253
174135	SV Sco	9.5	3212	5	246	..	3110	3	247	"	"	..	..	..	..	..	3368	4	248
"	"	..	..	..	..	..	3368	3	258	190108	R Aql	6.6	3246	5	313	11.8	3128	4	315
174162	W Pav	..	3116	3	269	..	3300	3	287	190529a	V Lyr	8.8	3170	4	362	15.0	3064	2	364
"	"	8.6	3403	5	287	..	..	..	..	190925	S Lyr	11.6	3198	4	451	..	..	..	..
174551	U Ara	..	3179	3	229	..	3297	3	..	190933a	RS Lyr	10.0	3350	5	315	15.0	3219	4	319
"	"	..	3403	3	224	..	..	..	..	190941	RU Lyr	10.3	3364	4	354	15.0	3200	4	359
175111	RT Oph	..	..	..	..	15.0	3288	5	429	190967	U Dra	9.2	3076	5	318	14.0	3254	5	322
175458a	T Dra	9.6	3273	5	395	12.5	3101	4	401	"	"	9.2	3393	5	317	..	..	..	..
175519	RY Her	9.2	3086	4	222	13.7	3214	5	224	191007	W Aql	7.8	3410	4	467	..	3240	3	448
"	"	9.2	3311	5	225	..	..	..	..	191017	T Sgr	..	3191	3	369	..	3389	3	363
175654	V Dra	9.7	3310	5	290	..	3165	3	279	191019	R Sgr	7.0	3226	5	276	..	3094	2	274
180363	R Pav	..	3156	3	231	..	3281	3	..	"	"	..	..	..	..	12.5	3366	4	272
"	"	8.0	3397	4	241	..	..	..	..	191033	RY Sgr	8.9	3309	5	..	..	..	..	..
180531	T Her	8.0	3196	5	165	12.9	3124	4	170	191319	S Sgr	..	3150	3	224	15.5	3273	4	..
"	"	7.6	3359	5	163	13.0	3278	5	154	"	"	9.8	3380	4	230	..	..	..	..
180565	W Dra	9.9	3223	5	273	..	3121	3	281	191331	SW Sgr	10.2	3309	5	289	..	3182	2	302
"	"	..	..	..	..	..	3368	3	247	191637	U Lyr	9.0	3400	4	455	11.7	3156	4	465
180666	X Dra	10.7	3120	4	272	15.5	3231	4	227	192928	TY Cyg	9.3	3374	5	334	15.0	3216	3	356
"	"	10.8	3330	4	210	..	..	..	..	193311	RT Aql	9.6	3276	5	318	..	3159	3	341
181031	TV Her	9.4	3337	5	307	..	3201	3	..	193449	R Cyg	6.7	3188	5	444	..	..	..	..
181103	RY Oph	7.9	3083	4	145	13.5	3173	4	153	193509	RV Aql	8.1	3174	4	216	..	3080	3	204
"	"	8.0	3240	5	157	13.5	3324	5	151	"	"	..	..	..	..	14.5	3294	4	214
"	"	8.0	3388	4	148	..	..	..	..	193972	T Pav	7.0	3070	4	244	..	3210	3	260
181136	W Lyr	8.1	3060	5	197	12.4	3170	5	206	"	"	8.1	3310	5	240	..	..	..	..
"	"	8.0	3270	5	210	12.3	3354	5	184	194048	RT Cyg	7.1	3087	5	187	11.6	3189	5	186
182133	RV Sgr	8.1	3249	5	310	..	3098	2	320	"	"	6.8	3274	5	187	11.9	3386	5	197
"	"	..	..	..	..	..	3411	3	313	194348	TU Cyg	9.8	3256	5	213	..	3154	3	216
182224	SV Her	..	3217	4	252	14.5	3100	4	231	"	"	..	..	..	..	14.5	3367	4	213

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
194604	X Aql	9.8	3120	4	368	14.5	3294	5	343	204215	U Cap	11.0	3299	5	..	242	3200	3	204
194632	x Cyg	4.7	3326	5	406	..	3160	3	397	"	"	..	..	..	..	15	3398	3	198
194659	S Pav	..	3419	3	379	10.3	3240	4	386	204318	V Del	..	..	..	..	16.0	3322	4	566
194929	RR Sgr	..	3090	3	328	..	3287	4	337	204405	T Aqr	8.0	3171	4	191	..	3083	3	204
195142	RU Sgr	7.0	3184	4	241	..	3084	3	244	"	"	7.4	3375	5	204	13.2	3274	5	191
"	"	..	..	..	..	13.0	3328	4	244	204846	RZ Cyg	..	3230	3	275	..	3120	3	322
195202	RR Aql	9.0	3188	3	380	..	3079	3	375	"	"	..	..	..	..	14.0	3367	5	247
195308	RS Aql	8.6	3283	5	409	..	3130	2	416	204954	S Ind	8.4	3419	5	404	..	3262	3	400
195849	Z Cyg	8.9	3219	5	252	13.9	3110	5	272	205017	X Del	8.6	3260	5	276	13.3	3146	4	283
"	"	..	..	..	..	14.7	3354	5	244	205627	RR Cap	7.8	3273	5	..	..	3185	3	..
200212	SY Aql	8.8	3124	5	340	14.0	3353	5	341	205923	R Vul	7.8	3178	4	139	13.0	3112	3	144
200357	S Cyg	..	3137	4	335	[16	3330	4	340	"	"	7.8	3314	5	136	13.5	3258	5	146
200514	R Cap	..	3126	3	294	12.7	3329	5	309	"	"	..	..	..	..	..	3386	4	128
200715a	S Aql	9.1	3184	4	184	11.2	3267	5	..	210124	V Cap	9.0	3293	5	271	..	3185	3	272
"	"	9.2	3340	5	156	11.6	3416	4	149	210129	TW Cyg	..	3108	3	372	[14	3266	4	367
200747	R Tel	8.2	3292	5	458	..	3111	3	461	210221	X Cap	..	3070	2	225	..	3179	1	217
200812	RU Aql	10.0	3212	4	280	..	3102	3	278	"	"	10.2	3279	4	209	13.6	3363	4	184
"	"	..	..	..	..	14.5	3378	4	276	210382	X Cep	..	..	..	..	[16	3260	4	510
200822	W Cap	..	3223	3	..	..	3351	3	..	210504	RS Aqr	9.7	3250	5	210	..	3149	3	..
200906	Z Aql	..	3163	3	129	..	3096	1	120	"	"	..	..	..	..	14.5	3370	3	221
"	"	9.8	3297	5	134	13.7	3242	5	146	210516	Z Cap	9.7	3318	4	378	..	..	..	..
"	"	..	..	..	..	13.6	3362	4	120	210812	R Equ	..	3147	2	254	14.3	3296	5	256
200938	RS Cyg	7.0	3410	4	400	9.0	3238	4	405	"	"	9.7	3404	4	257	..	..	..	..
201008	R Del	7.8	3237	5	277	13.3	3100	5	276	210868	T Cep	5.9	3193	5	401	10.6	3365	5	399
"	"	..	..	..	..	13.2	3390	4	290	210903	RR Aqr	9.3	3310	5	..	..	3224	2	..
201130	SX Cyg	..	3140	3	411	15.2	3386	4	405	"	"	..	..	..	..	..	3409	3	185
201139	RT Sgr	..	3117	3	316	12.7	3294	5	321	211614	X Peg	9.1	3162	3	204	..	3064	3	208
"	"	6.8	3416	4	299	..	..	..	..	"	"	9.0	3370	5	208	13.5	3259	5	195
201437b	WX Cyg	..	3240	3	..	..	..	..	..	211615	T Cap	9.5	3354	5	..	..	3250	3	..
201647	U Cyg	7.0	3153	5	453	11.4	3400	5	459	212030	S Mic	9.5	3362	5	..	..	3250	3	230
202240	U Mic	..	3138	3	330	..	3360	3	330	213678	S Cep	7.8	3338	5	456	10.2	3079	5	469
202622	RU Cap	9.2	3260	5	372	..	3141	3	361	213843	SS Cyg	8.3	3089	5	74	11.7	3118	5	63
202817	Z Del	9.0	3159	4	306	15.5	3328	5	298	"	"	8.6	3140	4	51	11.9	3160	4	42
202954	ST Cyg	10.0	3133	5	330	14.2	3314	5	316	"	"	8.4	3176	4	36	12.0	3206	5	46
203429	R Mic	..	3070	3	133	..	3141	1	131	"	"	8.3	3235	5	59	12.0	3277	5	71
"	"	..	3213	4	143	..	3279	4	138	"	"	8.3	3308	5	73	11.9	3328	5	51
"	"	8.7	3347	5	134	..	3419	3	140	"	"	8.4	3351	5	43	11.8	3372	5	44
203611	Y Del	..	..	..	..	13.5	3350	3	485	"	"	8.8	3392	5	41	11.8	3419	5	47
203816	S Del	..	3106	3	296	11.2	3240	5	296	214024	RR Peg	..	3102	3	255	14.0	3258	4	259
"	"	8.9	3378	4	272	..	..	..	..	"	"	9.0	3378	5	276	..	..	..	..
203847	V Cyg	7.8	3348	5	378	11.0	3194	4	484	214247	R Gru	8.6	3367	5	321	..	3232	3	325
203905	Y Aqr	9.2	3269	5	409	13.9	3110	3	402	215605	V Peg	..	3063	2	300	14.2	3223	3	294
204016	T Del	8.9	3057	5	337	14.5	3241	5	338	"	"	9.1	3345	5	282	..	..	..	..
"	"	9.0	3380	5	323	..	..	..	..	215828	S PsA	8.8	3300	5	..	..	3170	2	..
204104	WAqr	..	3142	3	394	13.3	3340	4	375	215934	RT Peg	..	3200	2	238	..	3320	3	..

Des.	Name	Maximum				Minimum				Des.	Name	Maximum				Minimum			
		Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.			Mag.	J. D.	Wt.	Int.	Mag.	J. D.	Wt.	Int.
215934	RT Peg	9.9	242 3402	5	<i>d</i> 202	..	242 ..	..	..	230110	R Peg	..	242 3126	3	<i>d</i> 382	13.3	242 3328	5	<i>d</i> 383
220412	T Peg	9.3	3198	4	350	14.3	3416	4	366	230759	V Cas	8.3	3098	5	234	13.4	3210	5	222
220613	Y Peg	..	3176	3	199	..	3091	3	196	"	"	7.6	3328	5	230	..	..	..	..
"	"	10.8	3389	4	213	15.5	3301	5	210	231425	W Peg	8.0	3091	5	358	12.6	3271	5	354
220714	RS Peg	9.6	3286	5	407	..	3160	3	467	231508	S Peg	..	3245	4	321	12.6	3094	3	317
221230	R PsA	9.0	3233	3	294	..	3380	2	..	"	"	..	..	..	..	12.7	3389	5	295
221321	X Aqr	7.6	3299	5	..	..	3142	3	..	232746	V Phe	8.8	3350	5	..	..	3226	2	251
221938	T Gru	8.4	3233	5	..	..	3167	2	..	233335	ST And	8.3	3095	5	337	11.0	3262	5	360
"	"	7.9	3367	5	134	11.4	3299	4	132	233815	R Aqr	6.0	3072	4	391	9.9	3299	5	397
221948	S Gru	7.2	3359	5	388	..	3210	3	390	233956	Z Cas	..	..	..	..	14.8	3311	5	493
222129	RV Peg	..	3310	3	390	..	3129	2	331	235053	RR Cas	10.6	3090	5	290	14.5	3260	5	308
222439	S Lac	7.9	3177	5	239	13.1	3063	5	233	"	"	11.0	3391	5	301	..	..	..	..
"	"	8.0	3416	5	239	13.3	3304	5	241	235150	R Phe	7.6	3349	5	..	..	3229	2	251
222867	R Ind	8.2	3201	4	211	..	3114	3	224	235209	V Cet	..	3179	2	276	14.0	3062	3	262
"	"	8.5	3419	5	218	..	3320	4	206	"	"	..	..	..	..	14.5	3310	5	248
223462	T Tuc	..	3154	3	250	13.2	3286	5	246	235265	R Tuc	..	3153	1	293	..	3330	3	290
"	"	7.9	3406	4	252	..	..	..	..	"	"	9.1	3440	5	287	..	..	..	..
223841	R Lac	7.8	3230	5	304	14.0	3100	4	291	235350	R Cas	6.5	3392	5	424	12.3	3236	5	439
"	"	..	..	..	..	14.6	3400	5	300	235525	Z Peg	..	3142	3	309	13.1	3331	5	331
225120	S Aqr	8.3	3329	5	274	..	3225	3	275	235715	W Cet	8.7	3100	3	362	14.4	3299	4	349
225914	RW Peg	..	3170	1	199	14.0	3082	3	210	235855	Y Cas	9.9	3096	5	426	14.5	3350	4	450
"	"	9.0	3379	5	209	13.5	3290	4	208	235939	SV And	8.4	3269	4	309	..	3139	3	319

REMARKS

001838. R Andromedae. Maximum 3055 revised to read 3070.
 024356. W Persei. Minimum 2860 revised to read 2900.
 030514. U Arietis. Minimum 3038 revised to read 3018.
 052034. S Aurigae. Maximum 2880 revised to read 2920.
 054319. SU Tauri. Nearly constant brightness, magnitude 9.5, throughout the year.
 065203. X Monocerotis. Maximum 2980 revised to read 3000.
 140959. R Centauri. This variable has a very marked secondary maximum and minimum and accordingly the value of "Interval" has been taken as from

alternate maxima and minima rather than from the consecutive maxima and minima.

145971. S Apodis. The magnitude steadily increased during the year from 10.9 on J. D. 3170 to 10.0 on J. D. 3417.

152849. R Normae. See remark on 140959.

174406. RS Ophiuchi. Magnitude nearly constant at 11.4 throughout the year.

180911. Nova Ophiuchi No. 4. Magnitude gradually decreased from 12.0 on J. D. 3194 to 12.8 on J. D. 3384.

184300. Nova Aquilae No. 3. Magnitude nearly constant at 10.1 throughout the year.

195553. Nova Cygni No. 3. Magnitude gradually decreased from 10.0 on J. D. 3161 to 10.8 on J. D. 3420.

JULY 2, 1923.



HARVARD COLLEGE OBSERVATORY

CIRCULAR 245

THE DISTRIBUTION OF STARS OF SPECTRAL CLASS M

BY HARLOW SHAPLEY AND ANNIE J. CANNON

PRACTICALLY all the Class M stars in the Henry Draper Catalogue are giants. This conclusion can be reasonably deduced from what is now known of the relative frequency of giants and dwarfs among stars brighter than the ninth magnitude. The high luminosity of these stars is also evident from characteristics of their spectra. The absolute magnitude is probably somewhat brighter for the long period variables than for ordinary M stars.

The distances of invariable Class M giants can be readily computed when the apparent brightness is known. If the apparent magnitude is m , the formula $\log d = 0.2m + 1$, which is based on the mean absolute magnitude adopted in Harvard Circular 243, gives the distance, d , in parsecs, with a probable uncertainty of about fifteen per cent. This formula does not hold, of course, for the very infrequent dwarf stars that may be included in the catalogue, nor for cM stars.

With the use of the above relation between apparent magnitude and distance, it is possible to derive the parallaxes and give the space coordinates for the four thousand giant M stars in the Henry Draper Catalogue. When further information concerning the proper motions or radial velocities of these stars has been accumulated, it will be more appropriate than now to print a separate catalogue of M stars giving the galactic coordinates, apparent magnitudes, and positions in space. For the present the distribution will be considered only with respect to galactic concentration.

In the Henry Draper Catalogue there are 1312 M stars brighter than the eighth visual magnitude. The catalogue is selectively incomplete for fainter stars. Moreover, the present discussion is based on an early manuscript copy of the catalogue. Because of subsequent additions and corrections, the numerical details

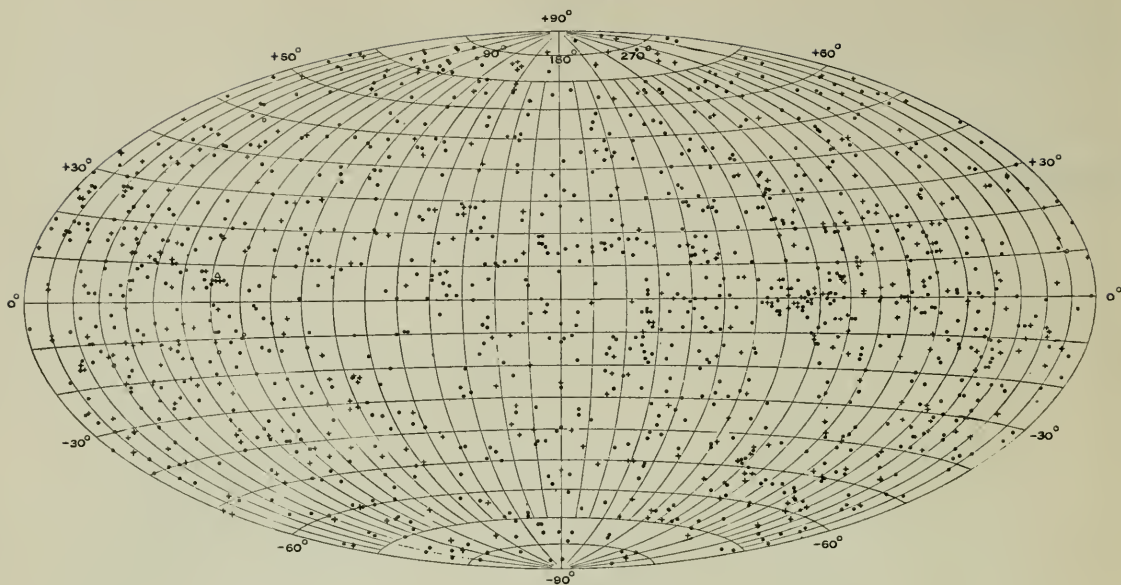


FIGURE 1.—Galactic distribution of Class M stars brighter than the eighth magnitude.

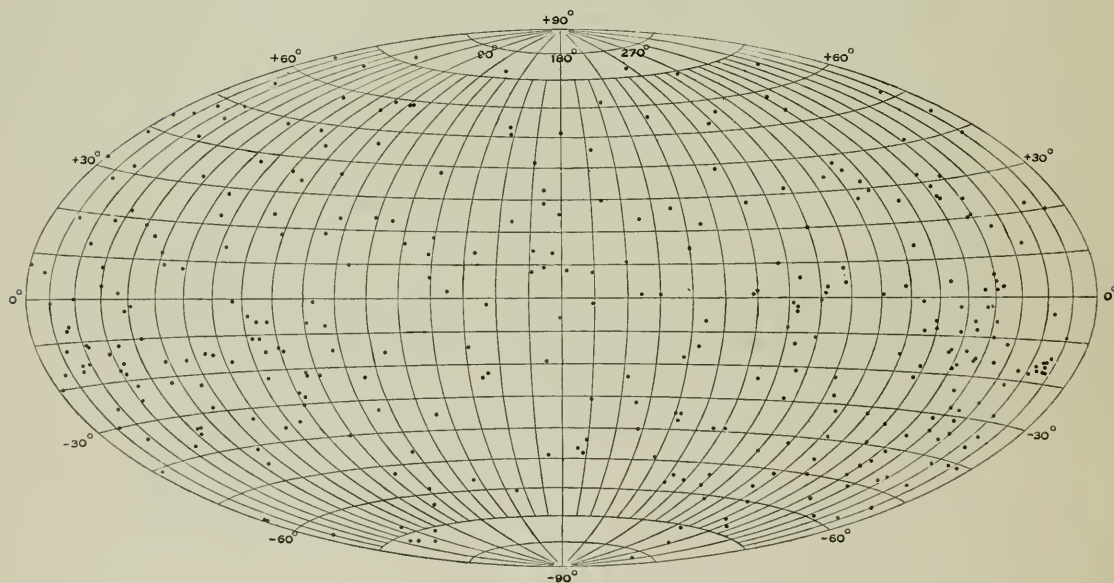


FIGURE 2.—Galactic distribution of stars of Class Md.

may not exactly coincide with those derivable from the volumes now printed, but the differences are immaterial.

The distribution in galactic coordinates for the stars brighter than the eighth magnitude is shown in Figure 1. Dots, crosses, open circles, and triangles, represent respectively stars of Classes Ma, Mb, Mc, and Md. The one Md star in this figure is H.R. 8383, which has little if any variation in magnitude (H.A. 56, 110, Remark 155).

The second figure shows the galactic distribution of the long period variables that are known to have bright lines in their spectra. Neither the irregular nor the periodic variables of Class M for which no bright lines have been observed are included. There are many variables, probably of Class Md, for which no information concerning the spectra is yet available. Figure 2 therefore gives an incomplete survey both for the Md stars and for the long period variables, but it suffices to indicate the degree of galactic concentration.

TABLE I
DISTRIBUTION IN GALACTIC LONGITUDE

Visual Magnitude	Spectral Class	Median Longitude												Total Number
		15°	45°	75°	105°	135°	165°	195°	225°	255°	285°	315°	345°	
J8.0	Ma	66	83	82	62	56	71	83	97	113	88	89	57	947
	Mb	37	44	31	23	19	16	21	17	44	40	42	24	358
	Mc	0	2	2	0	0	0	0	0	0	1	0	1	6
8.0 to 9.0	Ma	77	88	60	58	45	61	96	84	127	134	103	71	1004
	Mb	30	25	15	14	15	11	18	21	55	53	41	33	331
	Mc	2	5	3	0	1	1	1	1	2	2	5	2	25
[9.0	Ma	58	41	37	17	22	26	44	47	86	113	137	102	730
	Mb	49	19	16	16	8	18	17	22	46	65	78	48	402
	Mc	6	6	9	4	4	6	5	6	5	4	13	3	71
Variables	Md	38	36	26	29	11	20	17	19	29	31	54	31	341

Table I shows numerically the distribution of the M stars in galactic longitude. The tabulated quantities are the numbers of stars for intervals of thirty degrees in

longitude. The relatively greater number of stars fainter than the eighth magnitude between longitudes 180° and 360° suggests the better quality of the plates obtained at Arequipa for cataloguing the southern stars. But it may be largely explained by the greater real depth of the Milky Way in the direction of Sagittarius. The greater frequency in that direction is already established for planetary nebulae, novae, and other types of highly luminous stars. For the faint long period variables with spectra unclassified there is also a similar asymmetry.

TABLE II
DISTRIBUTION IN GALACTIC LATITUDE

Visual Magnitude	Spectral Class	Median Latitude									Total Number
		+80°	+60°	+40°	+20°	0°	-20°	-40°	-60°	-80°	
J8.0	Ma	21 (121)	76 (152)	108 (141)	187 (199)	199 (199)	144 (153)	108 (141)	78 (156)	26 (149)	947
	Mb	13 (75)	20 (40)	32 (42)	70 (74)	74 (74)	60 (64)	56 (73)	28 (56)	5 (29)	358
	Mc	0 (0)	0 (0)	1 (1)	1 (1)	2 (2)	2 (2)	0 (0)	0 (0)	0 (0)	6
8.0 to 9.0	Ma	12 (69)	41 (82)	104 (136)	175 (186)	275 (275)	208 (221)	108 (141)	68 (136)	13 (75)	1004
	Mb	4 (23)	11 (22)	25 (33)	51 (54)	95 (95)	71 (76)	45 (59)	25 (50)	4 (23)	331
	Mc	0 (0)	1 (2)	2 (3)	2 (2)	2 (2)	9 (10)	8 (10)	1 (2)	0 (0)	25
[9.0	Ma	6 (34)	18 (36)	51 (67)	128 (136)	192 (192)	188 (200)	92 (120)	43 (86)	12 (69)	730
	Mb	0 (0)	9 (18)	29 (38)	68 (72)	115 (115)	93 (99)	51 (67)	26 (52)	11 (63)	402
	Mc	1 (6)	8 (16)	5 (7)	14 (15)	17 (17)	15 (16)	5 (7)	6 (12)	0 (0)	71
Variables	Md	3 (17)	20 (40)	34 (44)	49 (52)	66 (66)	81 (86)	56 (73)	25 (50)	7 (40)	341

Table II gives the distribution in latitude. The tabulated quantities for each spectral class and interval of latitude are the actual numbers of stars and (in

parentheses) the numbers reduced to unit area. The concentration to the galactic circle is shown directly by the parenthetical numbers, which are plotted in Figure 3 for Ma and Mb stars.

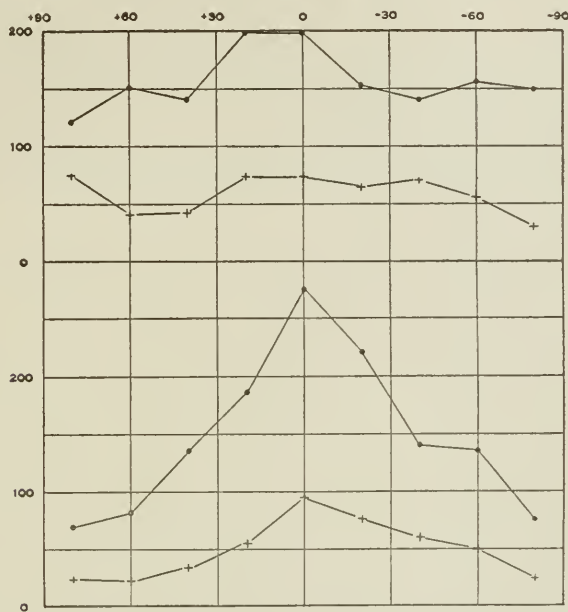


FIGURE 3.—Galactic concentration of Ma stars (dots) and Mb stars (crosses) for magnitudes brighter than eight in the upper part of the figure and magnitudes between eight and nine below. Ordinates are numbers of stars and abscissæ are galactic latitudes.

From the figures and tabular material the following conclusions may be drawn:

1. Stars of Class Mb, brighter than the eighth magnitude, show no galactic concentration. The Ma stars brighter than the eighth magnitude, however, are more numerous by thirty per cent per unit area between latitudes -10° and $+30^{\circ}$ than elsewhere.
2. Fainter than the eighth magnitude Ma and Mb stars are both strongly concentrated to the Galaxy, as shown by Table II.
3. The galactic concentration shown by Mc stars is not based upon enough stars to be well determined numerically.
4. Variables of Class Md appear to be concentrated to galactic latitude -20° ;

but the marked asymmetry in longitude is the more striking characteristic in the distribution of these stars.

5. In the direction of Taurus there is but one-half the average number of long period variables, and in the opposite direction (Sagittarius) there is twice the average number.

6. The fainter stars of Classes Ma, Mb, and Mc also show a strong preference for the region of Sagittarius which is not accounted for by the magnitude limitations of the Henry Draper Catalogue.

7. There are fifteen hundred giant M stars within five hundred parsecs of the Sun, and at least three thousand within eight hundred parsecs.

JULY 16, 1923

HARVARD COLLEGE OBSERVATORY

CIRCULAR 246

DISTANCES OF ONE HUNDRED AND SIXTEEN SOUTHERN STARS

BY HARLOW SHAPLEY

Parallaxes determined from the spectra for one hundred and sixteen bright southern stars, classed as G5, K2, and K5 in Harvard catalogues, are given below in Table I. The photographic material and the methods of reduction are similar to those described for K0 stars in Harvard Circular 243. The spectral classes have not been subdivided more closely than in the Henry Draper Catalogue, but α Mensac has been changed from K0 to G5. The measures were nearly all made by Miss Ames, and Miss Howarth has assisted in the reduction.

TABLE I

No.	H. D.	R. A. 1900	Dec. 1900	Vis. Mag.	H. D. Sp.	Abs. Mag.	Rel. Wt.	π
		<i>h m</i>	<i>° ' "</i>					"
328	2490	0 23.5	-40 28	5.33	K5	1.0	2	0.014
329	4308	0 40.4	-66 10	6.70	G5	2.5	1	0.014
330	5722	0 53.7	-11 55	5.79	G5	1.0	2	0.011
331	9053	1 24.0	-43 50	3.40	K5	0.4	2	0.025
332	11930	1 52.0	-23 1	5.18	K5	0.2	2	0.010
333	11937	1 52.0	-52 7	3.73	G5	3.0	2	0.072
334	12055	1 53.2	-47 53	4.74	G5	2.5	2	0.036
335	16417	2 32.8	-35 0	5.80	G5	3.3	1	0.032
11	18293	2 51.1	-75 29	4.70	K2	0.3	2	0.013
336 ¹	20794	3 15.9	-43 27	4.30	G5	6.0	2	0.219
14	23319	3 39.1	-37 38	4.64	K2	-0.2	2	0.011
337	27256	4 13.1	-62 43	3.36	G5	0.1	3	0.022
18	27442	4 14.7	-59 32	4.42	K2	0.9	2	0.020
338	28028	4 20.3	-34 15	4.06	K5	0.0	3	0.015
339	32887	5 1.2	-22 30	3.29	K5	1.0	2	0.035
340	36189	5 24.9	-59 0	5.06	G5	-0.6	2	0.007
341 ²	43834	6 13.2	-74 43	5.14	G5	5.3	3	0.108
342	44762	6 18.4	-33 23	3.98	G5	0.6	2	0.022
343	50337	6 47.6	-53 31	4.38	G5	0.2	2	0.015
344	52877	6 57.7	-27 47	3.68	K5	-0.5	1	0.015

No.	H. D.	R. A. 1900	Dec. 1900	Via. Mag.	H. D. Sp.	Abs. Mag.	Rel. Wt.	π
		<i>h m</i>	<i>° '</i>					<i>"</i>
345	56855	7 13.6	-36 55	2.74	K5	-0.2	2	0.026
346	59717	7 26.1	-43 6	3.27	K5	0.6	2	0.029
347	62644	7 39.9	-44 55	5.22	G5	4.0	2	0.057
348	64440	7 48.8	-40 19	3.76	G5	0.4	2	0.021
349	65685	7 54.7	-45 18	5.16	K5	-1.2	2	0.005
350	74006	8 36.2	-34 57	4.04	G5	-0.2	2	0.014
351	74772	8 40.8	-42 17	4.12	G5	-0.2	2	0.014
352	75605	8 45.8	-32 25	5.23	G5	1.5	2	0.018
353	75691	8 46.3	-27 21	4.19	K2	0.3	2	0.017
354	78647	9 4.3	-43 2	2.22	K5	-0.7	1	0.026
355	80108	9 12.7	-43 51	5.01	K5	-1.2	1	0.006
356	80230	9 13.4	-57 7	4.18	K5	-0.2	2	0.013
357	82150	9 25.1	-35 30	4.64	K2	0.1	2	0.012
358	82668	9 28.2	-56 36	3.04	K5	1.0	2	0.039
359	89388	10 13.7	-60 50	3.44	K5	-1.2	2	0.012
360	90610	10 22.6	-30 34	4.42	K5	-0.5	2	0.010
361	91942	10 31.8	-57 3	4.54	K5	-0.5	1	0.010
362	93497	10 42.5	-48 54	2.84	G5	0.4	3	0.033
363	98993	11 18.4	-35 37	5.12	K5	-0.5	2	0.008
364	100407	11 28.1	-31 18	3.72	G5	-0.3	3	0.016
365	102365	11 41.8	-39 57	5.04	G5	4.7	2	0.086
366	102839	11 45.2	-69 40	4.90	G5	-2.0	2	0.004
367	102462	11 49.7	-25 9	5.50	G5	2.5	1	0.025
368	109379	12 29.1	-22 51	2.84	G5	-0.3	2	0.024
369	109409	12 29.3	-44 7	5.86	G5	3.3	2	0.031
370	111915	12 47.5	-48 24	4.35	K2	0.6	2	0.018
371	112985	12 55.4	-71 1	3.63	K2	0.1	2	0.020
372	114613	13 6.5	-37 16	4.89	G5	1.8	2	0.024
373 ^s	115617	13 13.2	-17 45	4.80	G5	4.9	2	0.105
374	115659	13 13.5	-22 39	3.33	G5	0.6	3	0.028
375	124882	14 10.9	-83 13	4.14	K2	0.5	1	0.019
376	125383	14 13.9	-42 36	5.71	G5	-0.6	1	0.005
377	125932	14 17.4	-27 18	4.93	K2	0.6	2	0.014
378	128068	14 29.7	-45 49	5.41	K2	0.6	1	0.011
379	129078	14 35.4	-78 37	3.81	K5	0.0	3	0.017
380	130259	14 42.0	-25 40	5.39	G5	0.8	2	0.012
38	130694	14 44.5	-27 32	4.63	K2	0.9	2	0.018
381	132905	14 56.5	-63 38	5.22	G5	2.5	2	0.029
382	134270	15 3.8	-54 58	5.56	G5	-0.5	2	0.006
383	136422	15 15.5	-35 54	3.59	K5	0.6	4	0.025
384	139063	15 30.9	-27 48	3.78	K2	0.7	3	0.024
385	139127	15 31.3	-42 14	4.27	K5	1.1	4	0.023
386	139997	15 36.2	-19 21	4.96	K5	0.2	1	0.011
387	143546	15 55.8	-48 57	4.74	G5	0.8	3	0.016
388	150798	16 38.1	-68 51	1.88	K2	-0.7	2	0.030
389	151249	16 41.1	-58 52	3.68	K5	1.0	2	0.029
390	152311	16 47.5	-20 15	5.91	G5	1.8	1	0.015
391	152334	16 47.6	-42 12	3.75	K5	-0.1	4	0.017

No.	H. D.	B. A. 1900	Dec 1900	Vis. Mag.	H. D. Sp.	Abs. Mag.	Rel. Wt.	π
		<i>h m</i>	<i>° '</i>					<i>"</i>
392	152786	16 50.3	-55 50	3.06	K5	-0.3	3	0.021
393	152980	16 51.6	-53 0	4.15	K2	0.5	4	0.019
394	154948	17 3.5	-44 26	5.14	G5	-0.2	1	0.009
395	157236	17 17.0	-28 2	5.43	K2	0.9	1	0.012
396	157244	17 17.0	-55 26	2.80	K2	-0.7	4	0.020
397	158614	17 25.2	- 0 58	5.34	G5	4.0	2	0.054
398	160691	17 36.2	-51 47	5.26	G5	2.5	2	0.028
399	161892	17 43.0	-37 1	3.25	K2	0.6	3	0.030
400	163755	17 52.7	-30 14	5.27	K5	-1.2	1	0.005
401	164712	17 57.3	-75 53	5.69	K5	0.2	2	0.008
402	165185	17 59.6	-36 2	5.92	G5	3.3	1	0.030
403	167818	18 11.8	-27 5	4.69	K5	-0.2	2	0.011
404	168339	18 14.0	-61 33	4.25	K2	1.1	2	0.023
405	168415	18 14.4	-15 52	5.71	K2	0.9	2	0.011
408	169156	18 18.2	- 8 59	4.83	G5	0.6	3	0.014
406	169405	18 19.3	-48 10	5.48	G5	0.4	2	0.010
407	170845	18 26.4	-42 23	4.69	G5	-0.9	3	0.008
408	172051	18 32.9	-21 8	5.91	G5	4.8	2	0.060
409	173460	18 40.3	-22 30	5.80	K2	0.1	1	0.007
410	174974	18 48.1	-22 52	4.96	G5	-0.4	3	0.008
411	176704	18 56.4	-24 59	5.73	K2	0.4	2	0.009
412	177565	19 0.1	-37 57	6.27	G5	5.4	2	0.067
413	178345	19 3.1	-39 30	4.16	G5	-1.0	3	0.009
414	184492	19 29.6	-10 47	5.24	G5	-1.6	2	0.004
415	188376	19 49.7	-26 34	4.81	G5	2.8	4	0.040
48	188603	19 50.8	-27 26	4.62	K2	0.0	3	0.012
416	189005	19 52.8	-26 28	4.95	G5	-0.5	2	0.008
417	189567	19 55.5	-67 35	6.02	G5	5.4	1	0.075
418	189831	19 56.9	-38 13	4.79	K5	0.5	3	0.014
419	190248	19 58.9	-66 26	3.64	G5	2.5	3	0.059
420	192107	20 8.1	- 1 19	5.64	K2	1.1	2	0.012
421	192947	20 12.5	-12 51	3.77	G5	-0.2	2	0.016
422	196737	20 34.1	-33 47	5.54	K2	0.6	1	0.010
423	199951	20 55.2	-32 39	4.71	G5	-0.2	2	0.010
424		21 23.0	-22 15	4.59	G5	0.7	4	0.017
425		21 58.0	- 7 1	5.60	G5	-1.1	1	0.005
426		22 0.1	-40 2	4.60	K2	0.7	3	0.017
427		22 8.8	-21 35	5.45	G5	1.0	1	0.013
428		22 10.4	-42 8	5.19	G5	0.2	1	0.010
429		22 11.7	-60 45	2.91	K2	0.7	2	0.036
430		22 23.3	-44 0	4.02	G5	-0.6	4	0.012
431		22 47.7	-49 8	6.32	G5	4.0	1	0.034
432		22 55.0	-53 17	4.18	G5	0.3	4	0.017
433		23 1.3	-24 17	4.77	G5	0.4	3	0.013
434		23 13.9	-14 0	5.27	G5	1.8	2	0.020
435		23 15.9	-27 32	5.81	G5	1.6	2	0.014
436		23 20.8	-21 12	4.52	K5	1.4	2	0.024
437		23 46.2	-82 34	5.10	G5	1.0	2	0.015

The curves relating line intensity and absolute magnitude are based on the motions of more stars than appear in Table I; parallaxes of the additional stars will be published when the material is supplemented with plates now being made at Arequipa.

The variation of the intensity of the strontium lines for giant stars of Classes K2 and K5 is much less pronounced than for the giants of Classes G0 to K0 — a phenomenon that has also been noted, I believe, at Mount Wilson. For the K2 giants, in particular, there is not much gained in deriving individual absolute magnitudes except for a few of the brightest and faintest stars, since for the remainder it is nearly as satisfactory to adopt a mean value of +0.5.

TABLE II

No.	Name	Harvard Rel. Wt.	Spectrum		Parallax	
			Harv.	M. W.	Harv.	M. W.
339	ϵ Leporis	2	K5	K4	0.035	0.030
368	β Corvi	2	G5	G5	0.024	0.028
373	61 Virginis	2	G5	G8	0.105	0.105
374	γ Hydrae	3	G5	G7	0.028	0.025
397	Bu. S03S	2	G5	G6	0.054	0.063
108	ζ Scuti	3	G5	G8	0.014	0.013
421	α^2 Capricorni	2	G5	G8	0.016	0.030
433	ϵ^1 Aquarii	3	G5	G5	0.013	0.019
434	94 Aquarii	2	G5	G5	0.020	0.023

In Table II the Harvard and Mount Wilson parallaxes are compared for the stars common to Table I and to Mount Wilson Contribution 199. The systematic difference already noted in Harvard Circular 243 is again apparent, the Harvard absolute magnitudes averaging about three-tenths of a magnitude brighter.

1. ϵ Eridani, $\mu = 3''.168$.
2. α Mensae, $\mu = 0''.241$.
3. 61 Virginis, $\mu = 1''.529$.

AUGUST 4, 1923

LICK
OCT 5
UNIVERSITY OF CALIF.

HARVARD COLLEGE OBSERVATORY

CIRCULAR 247

LIGHT CURVES OF THE TWO ABNORMAL VARIABLES T AND R CORONAE BOREALIS

BY LEON CAMPBELL AND HARLOW SHAPLEY

Within a few degrees of each other, in the high galactic latitudes of $+47^\circ$ and $+50^\circ$, are found two of the most remarkable variable stars known — T Coronae, 155526, a nova of uncommon kind, and R Coronae, 154428, a peculiarly irregular variable which astronomers have studied for 140 years without arriving at an interpretation or attaining the least success in attempts to predict the variation. Light curves giving the complete photometric history of these two variables have been derived for the present discussion.

The most significant feature concerning T Coronae is its distance from the galactic circle. The forty or fifty other galactic novae on record are, without exception, in or near the Milky Way. Some novae have been found in fairly high galactic latitude in spiral nebulae. But T Coronae is not clearly associated with nebulosity of any kind, although, at a distance of five minutes of arc from the nova, Harvard photographs show a faint irregular nebula, which was first noted and measured by Barnard (*Ap. J.*, **25**, 281, 1907).

Before its discovery as a nova of the second magnitude, in 1866, by Birmingham, T Coronae was catalogued as B.D. $+26^\circ 27' 65''$, magnitude 9.5. Observations at the Lick and Mount Wilson Observatories show that the spectrum is now of Class M, somewhat peculiar in detail, but apparently with the characteristics of a giant star. As Lundmark has pointed out (*Pub. Ast. Soc. Pac.*, **34**, 225, 1922), the intrinsic brightness at maximum was very high, possibly excelling the luminosity of the Sun by fifty thousand times.

Figure 1 gives the graphical record of the light variations of T Coronae from 1866 to date, based on about seventeen hundred observations. The time scale in the upper part of the figure is ten times that of the remainder. Both the Julian days and the Calendar years are indicated for all sections of the figure. The ordinates are visual magnitudes, on the same scale throughout, reduced to the Harvard system. The open circles indicate means for all visual observers, except Schmidt

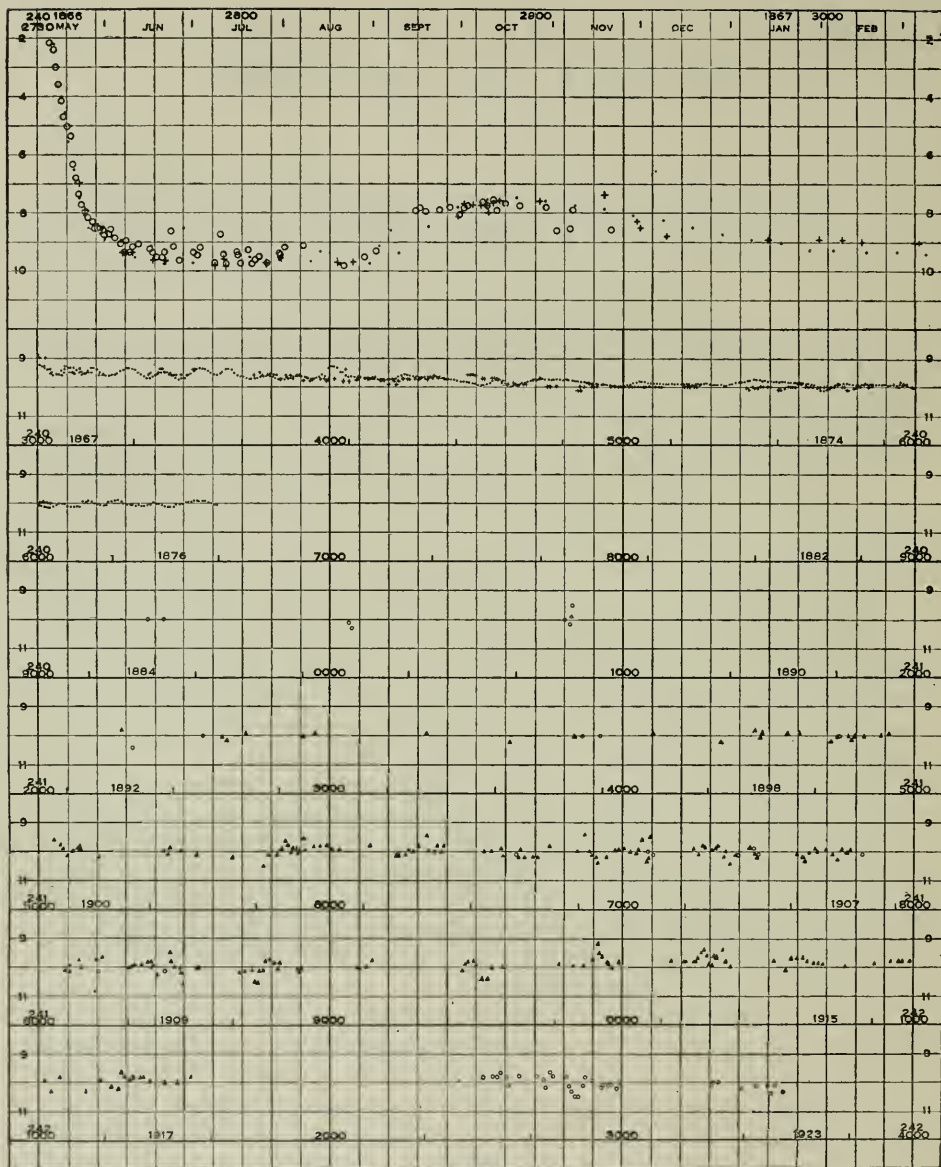


FIGURE 1.—Light Curve of T Coronae Borealis, 155526, from 1866 to 1923.

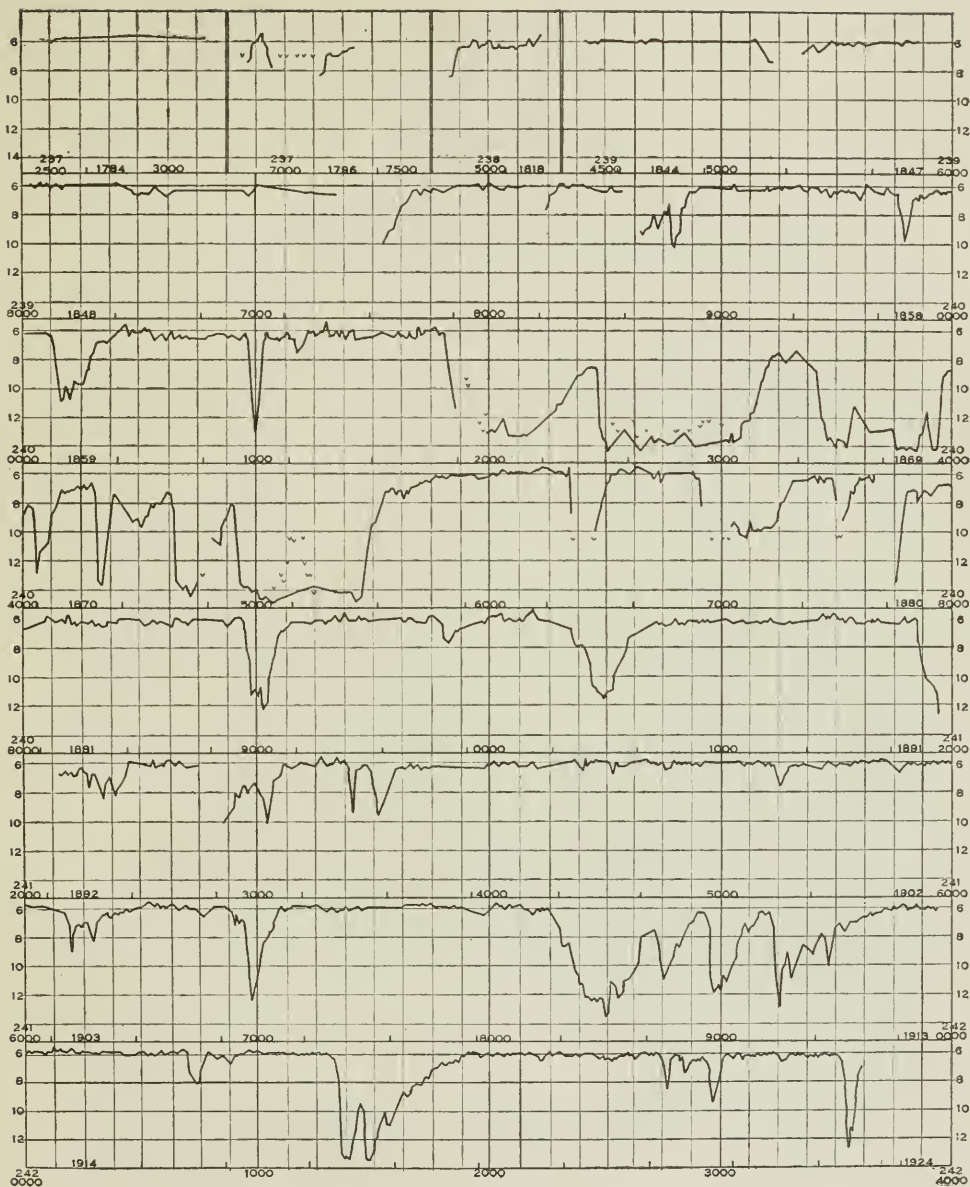


FIGURE 2.—Light Curve of R Coronae Borealis, 154428, from 1783 to 1923.

and Schönfeld, whose observations are represented by dots and crosses, respectively. The means were taken for each day near maximum, and for ten-day intervals thereafter. Schmidt's observations after September, 1866, were taken from his tabulated curve (A.N. 89, 83, 1877). The triangles indicate Harvard photographic observations (H.A. 84, 143, 1920), reduced to the visual scale. The visual observations since 1919 were all made by Mr. L. C. Peltier.

It is seen from the light curve that in 1866 the brightness fell off six magnitudes in twelve days, an uncommonly rapid decline for novae. The star had reached magnitude 9.5 one month after maximum, but later increased and remained brighter than the eighth magnitude for more than a month. For the last fifty years the star has varied only slightly, remaining near the tenth magnitude.

The variations of R Coronae, first observed by Pigott in 1783, are shown in Figure 2, which is based on approximately fifteen thousand observations, reduced when possible to the Harvard visual system. The curve connects ten-day means. The time and magnitude scales are uniform throughout the figure. Since 1843 the record has been practically continuous. The early material is essentially the same as that discussed by Ludendorff (Potsdam Publ., No. 57, 1908). From 1892 to date the observations are mainly those made at the Harvard Observatory, and by members of the American, British, and French variable star associations.

A remarkable feature of R Coronae is the uniformity in maximum brightness, which suggests that occultations, by star or nebula, play some part in the variation; but the spectral peculiarity and variability, noted by Espin, Frost, Ludendorff, and others, point rather to intrinsic variation in the star. It is apparently a giant, since the recent spectral classifications at Harvard and Mount Wilson give G0p and cF8, respectively, at maximum. The high galactic latitude is also noteworthy, since the other variables of this peculiar class are in or near the Milky Way.

It is quite possible that these two variables are at nearly the same distance from the Earth, and that some condition in that region of space accounts for such abnormal variation at a high galactic latitude. A reasonable value of the distance is about eight hundred parsecs. This would give +0.5 as the present absolute magnitude of T Coronae, which is an appropriate value for a giant star of Class M; and it would give -3.3 as the normal absolute magnitude of R Coronae, in agreement with several Cepheids which are of this same peculiar spectral type and have periods of ten days.

The distance separating the two variables, with the parallax as above, would be about fifty parsecs. The proper motions are very small.

HARVARD COLLEGE OBSERVATORY

CIRCULAR 248

SPECTRAL CLASS, APPARENT MAGNITUDE, AND GALACTIC POSITION FOR STARS OF THE HENRY DRAPER CATALOGUE

BY HARLOW SHAPLEY

Investigations of the distribution of the stars, for which spectral classes are given in the Henry Draper Catalogue, have been reported in six earlier papers. In Harvard Circular 226 the distribution in spectral type and visual magnitude is shown for the 222,570 stars of all common classes included in the manuscript catalogue; but in that treatment the positions in the sky are not considered. The relation of the brighter A stars to the local star cloud is discussed in Circular 229 on the basis of positions expressed in galactic coordinates. The distribution of the B stars, shown in Circular 239 for four different intervals of magnitude, brings out more clearly the existence and limits of the local cloud, and illustrates the high concentration to the Galaxy of the faint and very distant B stars. In Circular 240, which deals with the spectral constitution of the nearer parts of the Milky Way, the frequency of the various classes of spectrum is examined for different intervals of visual magnitude and galactic longitude, but only the lower latitudes are considered. Circular 243 contains a tabular summary of the distances of a hundred thousand stars of the Henry Draper Catalogue. Finally, the galactic distribution of all known stars of Class M is shown in Circular 245.

The material presented in Circular 240 is again used in the present discussion, in connection with the comparable data on spectrum, magnitude, and longitude now given for high galactic latitudes. The tables and diagrams show the galactic concentration for each spectral division, and for different intervals of magnitude. They also show the relative frequency of the spectral types for different galactic latitudes, thus extending the undifferentiated results of Circular 226. Miss Mabel Gill and Miss E. F. Leland have done the major part of the work of assembling the material for Table II. The diagrams were made by Miss Gill.

As formerly, the selected fields throughout which counts were made have each an area of one hundred square degrees. Table I gives the limiting right

TABLE I
SELECTED FIELDS OUTSIDE THE MILKY WAY

Longitude	Limits of R.A.				Limits of Dec.				Longitude	Limits of R.A.				Limits of Dec.				
Lat. = +90°									Lat. = -30°									
—	<i>h</i>	<i>m</i>	<i>h</i>	<i>m</i>	°	'	°	'	0	<i>h</i>	<i>m</i>	<i>h</i>	<i>m</i>	°	'	°	'	
Lat. = +75°	12	17.3 to 13	2.6		+23	10 to +33	9		60	20	7.4 to 20	48.5		-18	39 to -	8	40	
0	13	25.2	14	10.0	+22	0	+31	59	120	2	23.9	23	8.0	+20	30	+30	29	
120	11	35.1	12	28.1	+35	57	+45	56	180	2	11.9	2	56.0	+20	30	+30	29	
240	11	48.3	12	29.7	+9	53	+19	52	240	4	31.4	5	12.5	-18	39	-	8	40
Lat. = +60°									300	5	7.5	6	38.4	-69	9	-59	10	
0	14	31.0	15	14.9	+19	10	+29	9	Lat. = -45°									
90	12	2.2	13	17.7	+53	20	+63	19	45	22	18.8	22	59.2	+1	14	+11	13	
180	10	5.0	10	48.9	+19	10	+29	9	135	2	20.8	3	1.2	+1	14	+11	13	
270	12	20.0	12	59.9	-6	59	+2	59	225	3	36.4	4	39.6	-55	38	-45	39	
Lat. = +45°									315	20	40.4	21	43.6	-55	38	-45	39	
45	15	36.4	16	39.6	+45	39	+55	38	Lat. = -60°									
135	8	40.4	9	43.6	+45	39	+55	38	0	22	5.0	22	48.9	-29	9	-19	10	
225	10	18.8	10	59.2	-11	13	-1	14	90	0	20.0	0	59.9	-2	59	+6	59	
315	14	20.8	15	1.2	-11	13	-1	14	180	2	31.0	3	14.9	-29	9	-19	10	
Lat. = +30°									270	0	2.2	1	17.7	-63	19	-53	20	
0	16	31.4	17	12.5	+8	40	+18	39	Lat. = -75°									
60	17	7.5	18	38.4	+59	10	+69	9	0	23	10.0	23	54.9	-31	59	-22	0	
120	6	41.5	8	12.4	+59	10	+69	9	120	0	50.1	1	31.5	-19	52	-9	53	
180	8	7.4	8	48.5	+8	40	+18	39	240	0	51.9	1	44.9	-45	56	-35	57	
240	10	23.9	11	8.0	-30	29	-20	30	Lat. = -90°									
300	14	11.9	14	56.0	-30	29	-20	30	—	0	17.3	1	2.6	-33	9	-23	10	

ascensions and declinations for the selected fields outside of the Galaxy and is, therefore, a direct continuation of Table I in Circular 240.

Table II is completely analogous to the table of the same number in Circular 240. Stars fainter than visual magnitude 8.25 are again omitted from the investigation because of the incompleteness of the catalogue (in the northern sky, at least) for stars fainter than that limit.

A summary of Table II is given in Table III, which is used as a basis for the principal diagrams illustrating the distribution of the various types. A casual inspection of Table II shows that the concentration to the galactic plane is not uniform for all galactic longitudes. This condition is to be expected when we consider our eccentric position in the local cloud and in the general galactic system. To examine the diversity for different longitudes further, Table IV has been constructed. It shows, for four different intervals of galactic longitude, the average number of stars per hundred square degrees brighter than the visual magnitude 8.25 in each belt of latitude. The first quarter of longitude, from 10° to 90°, represents

TABLE II
NUMBER OF STARS IN ONE HUNDRED SQUARE DEGREES FOR EACH SPECTRAL CLASS AND FOR
DIFFERENT GALACTIC LATITUDES AND LONGITUDES

Galactic Latitude	Galactic Longitude	Magnitudes brighter than 6.0						Magnitudes 6.0 to 7.0						Magnitudes 7.0 to 8.25						Total Number
		B	A	F	G	K	M	B	A	F	G	K	M	B	A	F	G	K	M	
°	°																			
+90	...	0	6	1	3	2	1	0	8	3	1	7	0	0	3	10	18	29	7	99
+75	0	0	1	1	2	2	1	0	1	2	3	4	0	0	6	16	6	37	6	88
+75	120	0	1	1	0	2	1	0	1	1	3	7	1	0	11	5	24	39	6	103
+75	240	0	3	0	0	2	0	0	4	1	0	8	0	0	3	8	15	29	7	80
+60	0	0	2	1	1	7	3	0	7	1	3	9	1	0	4	6	19	31	5	100
+60	90	0	4	2	1	1	2	0	1	0	2	6	1	0	10	5	16	43	4	98
+60	180	0	2	1	3	2	0	0	3	2	2	8	0	0	4	8	12	22	5	74
+60	270	0	2	1	0	0	0	0	3	3	5	6	2	0	5	11	11	25	7	81
+45	45	1	6	2	0	1	1	0	5	1	1	8	2	0	9	6	16	50	5	114
+45	135	0	5	2	3	2	0	0	9	4	3	3	0	1	9	8	16	38	6	109
+45	225	0	2	0	0	2	2	0	3	1	1	6	2	0	11	5	8	28	10	81
+45	315	0	1	1	1	3	2	0	5	2	2	7	0	0	9	5	20	31	3	92
+30	0	0	5	0	0	3	4	1	6	2	5	8	2	0	18	11	13	38	17	133
+30	60	1	3	0	3	2	0	0	6	3	2	5	2	0	17	11	13	34	12	114
+30	120	1	0	2	2	3	0	0	8	5	2	7	1	0	10	19	30	32	10	132
+30	180	0	5	2	0	2	2	0	5	4	1	11	2	0	25	9	17	42	3	130
+30	240	0	4	0	2	1	2	0	6	1	5	8	0	0	18	11	15	45	17	135
+30	300	0	4	1	2	7	1	0	5	1	4	7	0	0	17	15	18	44	7	133
-30	0	1	5	1	2	4	1	0	5	2	4	10	0	0	19	19	28	40	8	149
-30	60	0	1	1	1	4	1	0	3	1	0	4	1	1	20	12	14	35	8	107
-30	120	1	7	1	2	1	0	0	4	3	1	3	2	0	15	12	15	33	3	103
-30	180	3	5	2	2	6	1	2	8	2	3	4	1	0	25	6	16	29	8	123
-30	240	1	2	1	1	4	1	2	8	5	4	4	2	0	25	14	20	43	3	140
-30	300	1	3	0	2	5	2	1	9	2	3	9	2	0	32	11	23	45	7	157
-45	45	1	2	1	3	3	0	0	4	3	3	2	0	0	4	13	18	29	5	91
-45	135	2	2	1	0	3	1	0	4	5	3	10	3	0	14	14	15	21	3	101
-45	225	0	1	0	1	2	0	0	3	3	4	7	1	1	10	20	17	47	3	120
-45	315	0	0	2	1	3	1	0	4	2	3	9	3	0	15	13	27	47	9	139
-60	0	0	2	1	2	4	1	0	3	0	7	5	2	0	10	7	23	33	6	106
-60	90	0	1	0	1	3	0	0	3	1	1	10	1	0	4	13	16	24	3	81
-60	180	0	2	3	0	4	0	0	4	1	3	8	0	0	8	3	13	37	12	98
-60	270	0	2	1	1	3	0	0	2	1	8	5	0	0	10	7	17	31	7	95
-75	0	0	1	0	0	1	1	0	5	0	3	7	3	0	6	11	21	33	6	98
-75	120	0	2	2	0	5	0	0	0	3	4	4	0	0	8	10	7	23	2	70
-75	240	0	2	1	0	4	1	0	2	4	0	9	0	0	4	8	16	29	7	87
-90	...	1	2	0	0	4	0	0	4	2	1	11	1	0	3	11	18	36	7	101

the Aquila-Cygnus section of the Milky Way. The second includes the star groups and extensive dark nebulosities in Perseus, Taurus, and northern Orion.

TABLE III

AVERAGE NUMBER OF STARS IN ONE HUNDRED SQUARE DEGREES FOR DIFFERENT LATITUDES.
SUMMARY OF TABLE II FOR CONSTRUCTION OF DIAGRAMS

Galactic Latitude	Number of Fields	Magnitudes 7.0 to 8.25							All magnitudes brighter than 8.25						
		B	A	F	G	K	M	All	B	A	F	G	K	M	All
°															
+90	1	0	3	10	18	29	7	67	0	17	14	22	38	8	99
-90	1	0	3	11	18	36	7	75	1	9	13	19	51	8	101
+75	3	0	6.7	9.7	15.0	35.0	6.3	72.7	0	10.3	11.7	17.7	43.3	7.3	90.3
-75	3	0	6.0	9.7	14.7	28.3	5.0	63.7	0	10.0	13.0	17.0	38.3	6.7	85.0
+60	4	0	5.8	7.5	14.5	30.2	5.2	63.2	0	11.8	10.2	18.8	40.0	7.5	88.3
-60	4	0	8.0	7.5	17.2	31.2	7.0	70.9	0	12.8	9.5	23.0	41.8	8.0	95.1
+45	4	0.2	9.5	6.0	15.0	36.8	6.0	73.5	0.5	18.5	9.2	17.8	44.8	8.2	99.0
-45	4	0.2	10.8	15.0	19.2	36.0	5.0	86.2	1.0	15.8	19.2	23.8	45.8	7.2	112.8
+30	6	0	17.5	12.7	17.7	39.2	11.0	98.1	0.5	27.0	16.2	22.3	49.8	13.7	129.5
-30	6	0.2	22.7	12.3	19.3	37.5	6.2	98.2	2.2	32.7	15.8	23.5	47.2	8.5	129.9
+10	11	2.6	49.7	11.9	17.9	51.5	13.2	146.8	5.7	65.4	15.7	22.2	63.7	15.7	188.4
-10	14	6.5	65.6	14.1	17.6	47.7	12.5	164.0	16.1	82.7	18.1	22.0	61.1	15.9	215.9
0	23	18.9	75.8	13.6	20.9	53.9	13.6	196.7	29.7	96.9	18.7	26.0	69.0	17.5	257.8
Milky Way	..	18.8	69.2	4.1	4.5	21.1	7.5	125.2	29.4	83.7	6.2	6.2	26.1	9.9	161.5

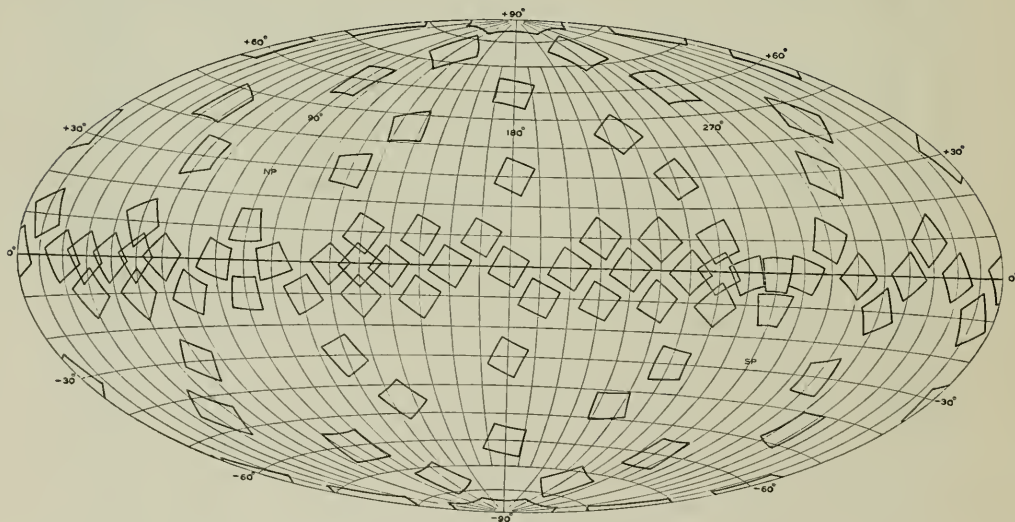


FIGURE 1.— Distribution of selected fields.

TABLE IV

GALACTIC CONCENTRATION CONSIDERED SEPARATELY FOR FOUR INTERVALS OF LONGITUDE,
MAGNITUDES 18.25

Galactic Latitude	Number of Fields	B	A	F	G	K	M	All Classes	Galactic Latitude	Number of Fields	B	A	F	G	K	M	All Classes
Gal. Long. 10° to 90°		I							Gal. Long. 190° to 270°		III						
+90	1	0	17	14	22	38	8	99	+75	1	0	10	9	15	39	7	80
+60	1	0	15	7	19	50	7	98	+60	1	0	10	15	16	31	9	81
+45	1	1	20	9	17	59	8	114	+45	1	0	16	6	9	36	14	81
+30	1	1	26	14	18	41	14	114	+30	1	0	28	12	22	54	19	135
+10	3	5	72	15	22	58	15	187	+10	3	7	63	19	19	70	25	203
0	6	25	130	19	28	80	18	300	0	6	48	103	22	23	74	26	296
-10	4	12	103	19	25	72	22	253	-10	5	25	91	19	19	67	18	239
-30	1	1	24	14	15	43	10	107	-30	1	3	35	20	25	51	6	140
-45	1	1	10	17	24	34	5	91	-45	1	1	14	23	22	56	4	120
-60	1	0	8	14	18	37	4	81	-60	1	0	14	9	26	39	7	95
-90	1	1	9	13	19	51	8	101	-75	1	0	8	13	16	42	8	87
Gal. Long. 100° to 180°		II							Gal. Long. 280° to 360°		IV						
+75	1	0	13	7	27	48	8	103	+75	1	0	8	19	11	43	7	88
+60	1	0	9	11	17	32	5	74	+60	1	0	13	8	23	47	9	100
+45	1	1	23	14	22	43	6	109	+45	1	0	15	8	23	41	5	92
+30	2	0	26	20	26	48	9	129	+30	2	0	28	15	21	54	16	134
+10	3	3	72	16	25	67	11	194	+10	2	10	48	12	24	60	10	164
0	6	20	78	18	28	62	10	216	0	5	26	72	15	25	58	16	212
-10	3	9	57	18	26	41	9	160	-10	2	13	61	16	18	56	9	173
-30	1	5	38	10	21	39	10	123	-30	2	2	36	18	31	56	10	153
-45	1	2	20	20	18	34	7	101	-45	1	0	19	17	31	59	13	139
-60	1	0	14	7	16	49	12	98	-60	1	0	15	8	32	42	9	106
-75	1	0	10	15	11	32	2	70	-75	1	0	12	11	24	41	10	98

The center of the local cluster is in the third quarter, and the direction toward the center of the galactic system lies in the fourth, where the distribution for the giant stars is also undoubtedly influenced by the large obscuring nebulosities in Ophiuchus and Scorpio.

The main results of the present study are sufficiently summarized by discussing in turn the various figures.

1. The distribution of the selected fields covered by the investigation is shown in Figure 1, which employs the galactic system of coordinates (Aitoff's projection). The inequalities of stellar distribution along the Milky Way necessitate the use of more fields than in the higher latitudes.

The counts were made between limits of right ascension and declination, so computed that the center of gravity of each field falls close to a chosen point with galactic coordinates as given in the first and fourth columns of Table I. More than one fifth of the sky is covered by these selected fields.

2. The fourteen diagrams of Figure 2 are based on the average numbers in columns three to sixteen of Table III, and show the galactic concentration for different spectral types. The spectral divisions appearing in the tables and

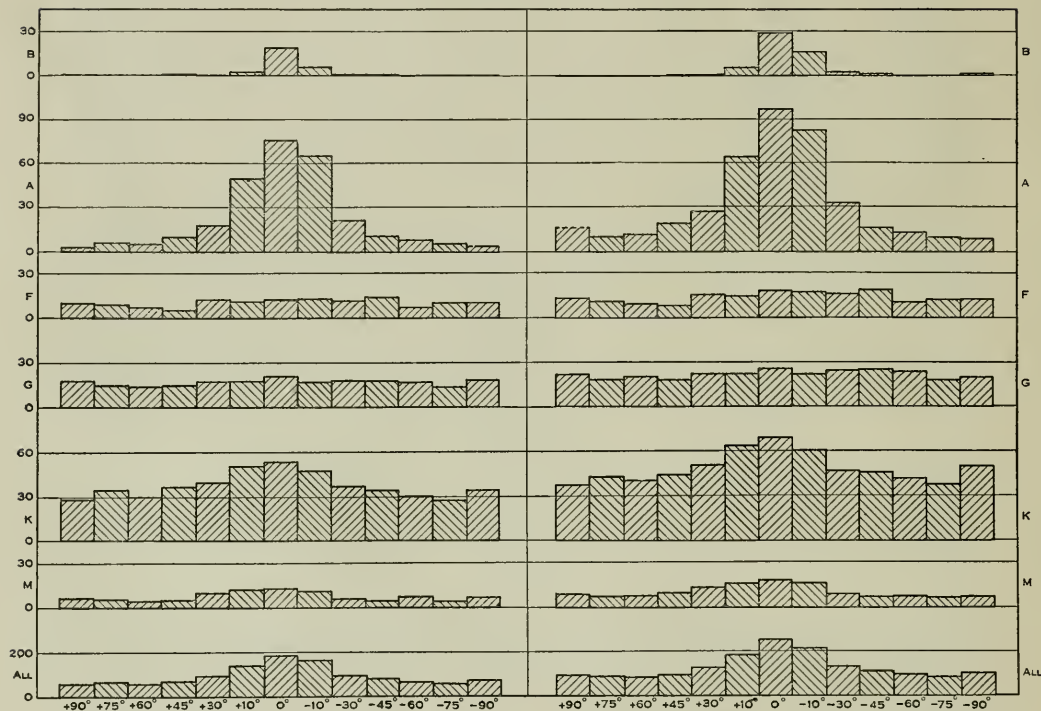


FIGURE 2.— The concentration of stars toward the galactic circle. Abscissas are galactic latitudes. Ordinates are average numbers of stars for each 100 square degrees. The diagram on the left refers to stars between magnitudes 7.0 and 8.25, and on the right, to all stars brighter than magnitude 8.25.

diagrams include subdivisions as follows: B (B0 – B5), A (B8 – A3), F (A5 – F2), G (F5 – G0), K (G5 – K2), M (K5 – Mc). The two diagrams for “all” stars, at the bottom of the figure, are on a reduced scale.

The seven diagrams on the left of Figure 2, for stars between magnitudes 7.0 and 8.25, show the following features:

- a. The predominance of A and K stars, especially in the Milky Way. This is better shown in Figures 5 and 6.
- b. Little or no galactic concentration of F and G stars.
- c. Very sharp contrast in concentration between B8 – A3 and A5 – F2 stars, suggesting either a discontinuity in the spectral series or the operation of an important selection.

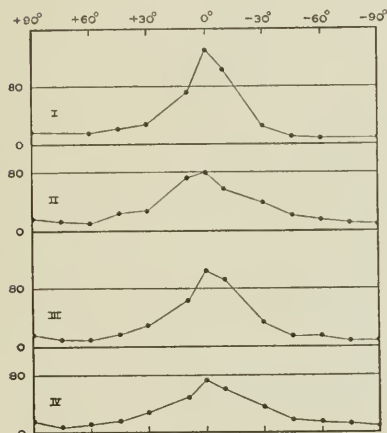


FIGURE 3.—Galactic concentration of stars of Class A in four quarters of galactic longitude. Ordinates and abscissas as in Figure 2.

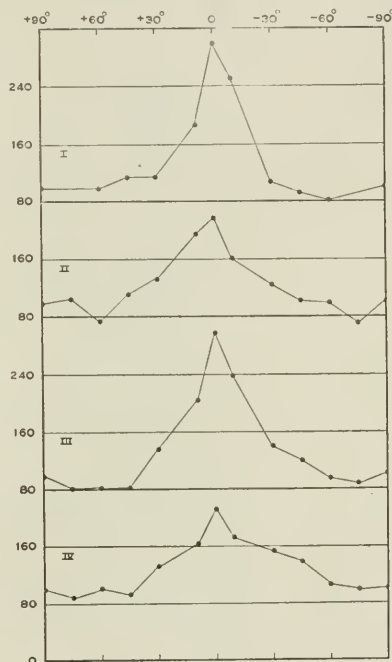


FIGURE 4.—Galactic concentration, for stars of all spectral classes combined, in four quarters of galactic longitude.

- d. Fairly uniform density between 45° and 90° in both hemispheres for all spectral divisions except A. (For the B stars with latitudes greater than $\pm 50^\circ$, see Harvard Circular 239.)

- e. A slightly greater density for F, G, and M stars at the poles than at latitudes 60° and 75° . This unexpected condition may be of little significance, since the number of stars involved is small; but it appears conspicuously also for the K stars in the south galactic hemisphere, and for stars of all types together, brighter than magnitude 8.25 (*Cf.* last diagram on the right of Figure 2). An investigation

by W. H. Pickering has already indicated the existence of a cluster of G0 and G5 stars near the south galactic pole (Pub. A. S. P., June, 1921).

The diagrams on the right of Figure 2, for stars of all magnitudes to 8.25, show features similar to those just mentioned. The excess of B and A stars in southern latitudes near the galactic equator probably results from the "dip" of the local system. Elsewhere the differences between the two hemispheres are not significant, except for the bright group of A stars in Coma at the north galactic pole.

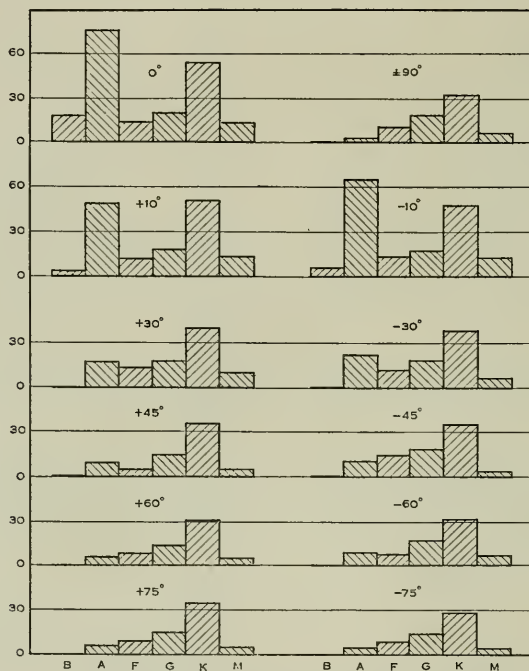


FIGURE 5.—The relative frequency of spectral type in different galactic latitudes for stars between magnitudes 7.0 and 8.25. Ordinates are average numbers of stars in 100 square degrees.

In partial explanation of the various contrasts in galactic concentration, it should be noticed that B, A, K, and M stars of the Henry Draper Catalogue are mostly giants, and that the F and G stars are largely dwarfs. Some G5 dwarfs are included, but exceedingly few dwarfs of later classes are among the stars here considered. The amount of space represented is therefore very different for the various spectral divisions. For instance, the volume completely sampled for the

G stars can be roughly placed at a million cubic parsecs, while the volume from which the B stars have been collected is two thousand times as great.

In Harvard Bulletin 792, the frequency in space of the various classes of stars is estimated on the basis of the apparent spectral distribution along the Milky

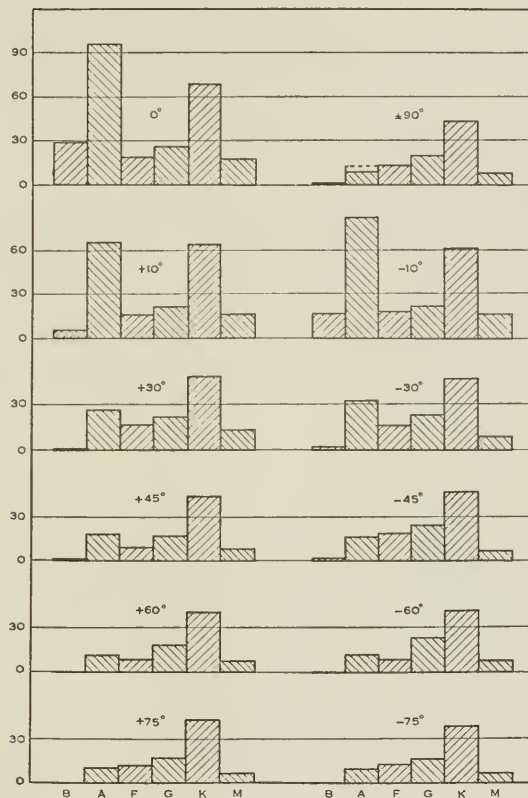


FIGURE 6.—The relative frequency of spectral type in different galactic latitudes for all stars brighter than 8.25.

Way (Table III), using average values of the absolute brightness of the stars of different classes. It is found that the relative frequency in space of G and B stars is approximately as two thousand to one.

3. The galactic concentration for four different quarters of galactic longitude is shown for A stars and for stars of all classes in Figures 3 and 4, which are based on

the material presented in Table IV. These contrasted curves show clearly that galactic longitude is an important factor in the study of galactic concentration. It is difficult to explain satisfactorily all the differences between the curves for the four quarters. There are clear evidences of the effect of the local system, the Cygnus star cloud, the eccentric position of the Sun, the dark nebulosities in Taurus, and the great rift in the Milky Way which influences the curves for the fourth quarter. The discussions by Nort and Pannekoek of star counts based on the Harvard Map of the Sky have already brought out some of these features, but the spectral classes, of course, were not then differentiated. The undeniable heterogeneity of our part of the galactic system appears to make a closer analysis of star counts of little meaning.

4. The frequency of the spectral classes at different galactic latitudes is shown graphically in the twenty-four diagrams of Figures 5 and 6. The preponderance of division A in low latitudes and of division K in high latitudes is a conspicuous feature.

5. The spectral composition of the excess of stars along the Milky Way is shown by the bottom row of numbers in Table III and by the two diagrams in Figure 7. Each value is obtained by subtracting from the corresponding total for

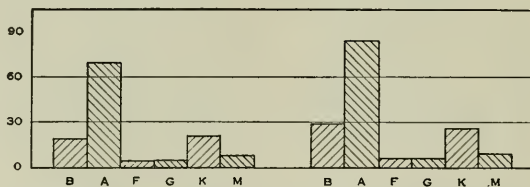
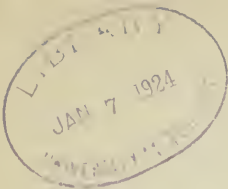


FIGURE 7.—The Milky Way excess. The magnitude interval from 7.0 to 8.25 is represented on the left; all magnitudes brighter than 8.25, on the right.

zero latitude the mean of the corresponding values of the first eight rows of Table III. That is, the average content of one hundred square degrees from latitude 45° to the poles is deducted from the average content for the Milky Way zone. The diagrams illustrate, as would be expected, that the distant Milky Way regions are represented chiefly by the giant stars.



HARVARD COLLEGE OBSERVATORY

CIRCULAR 249

COMPARISON OF PHOTOGRAPHIC MEASURES MADE BY DIFFERENT OBSERVERS

BY EDWARD S. KING

Professor G. P. Bond, in discussing stellar photographs obtained on wet plates in 1857 at Harvard (A.N. 49, 81, 1858), made the following statement: "Photographs of stars of unequal brightness present marked peculiarities in size and intensity, when their images formed by equal exposures are compared together; at once suggesting the possibility of classifying them according to a scale of photographic or chemical magnitudes, analogous to the common optical scale, but differing from it essentially, in the fact of its being based upon actual measurements, in place of the vague and uncertain estimates to which astronomers have hitherto resorted in attempting to express with numbers the relative brightness of different stars." From a study of a series of exposures to the stars Mizar, Alcor and Vega, he determined a parabolic relation connecting the length of exposure with the diameter of the corresponding image.

Many astronomers have since used the diameter of the photographic image as a measure of brightness, and have derived various formulae to express the relation. At Harvard the practice has been to compare each image to be measured with a graded series of similar images obtained by photographing some star with exposures progressing in geometrical ratio. A small section bearing the images of the star thus photographed forms a convenient scale of magnitudes. Such a scale having been placed in contact with the plate, a direct comparison of the images to be measured is effected by using a 2-inch eyepiece. The readings are made to tenths of a division of the scale, reckoned from the brighter to the fainter image. This method takes into account not only the size of the image, but its blackness and general appearance. Comparison may also be made conveniently by using the scale of magnitudes in place of the wedge in a Hartmann photometer. In any case, the scale readings do not give magnitudes directly, but are used in a purely differential way.

The measures relating to eclipses of Jupiter's satellites (H. A. 80, No. 10, 1916)

were made with a photographic scale (Plate IV, Fig. 5, H. A. 59, No. 7, 1912), cut from a plate, C 14147, taken with the 11-inch Draper telescope. This scale consisted of nine images of one star photographed in a series of different exposures, the exposure being halved for each successive image. The brightest image was marked "1," and the faintest one "9." To select capable observers and to determine the accuracy of the measures, a preliminary test was conducted with this scale on a plate of the Pleiades, C 14146, showing images resulting from four consecutive exposures of different lengths. Twelve stars having been marked for measurement, the procedure was as follows: (1) The arrangement of the images and the method of measuring were briefly explained. (2) The observer was supplied with a blank form providing for forty-eight possible measures, and was cautioned to record unmeasurable images as "too bright," "faint," or "not seen." (3) He was instructed to record also the times of beginning and ending the measures, the date, and his signature. (4) After the results were handed in, the observer was asked to remeasure the plate. The mean of the two measures of each star was accepted, provided there was no patent mistake. This test, which included observers familiar and unfamiliar with the work, resulted favorably for the employment of intelligent persons, even though inexperienced in such comparisons. The same plate and scale have been used since to test the accuracy of different observers and an account of the results is herewith given.

In 1903, when these tests were first made, measures of twenty-one star images made by six observers showed that the average deviation for a single observer for a single image was ± 0.18 divisions of the scale; the average deviation for a single observer for the mean of twenty-one images was ± 0.04 divisions. For three of the observers who were without previous experience the above quantities were ± 0.19 and ± 0.05 .

A more complete discussion includes twelve observers, two of whom measured the test plate again after an interval of ten years. The observers were H. R. Colson, A. Ellenbogen, E. S. King, E. T. King, R. W. Lynn, L. H. Thibault, and Misses H. S. Leavitt, E. F. Leland, J. C. Mackie, G. F. Matthews, M. E. O'Reilly, and A. D. Walker. The first four columns of Table I give the observer designated arbitrarily by letter, the date when the test was made, the light used, and the time occupied in measurement. The fifth column gives the mean of the differences, first minus second measure, for twenty-four star images. The sixth column gives the average of the differences taken without respect to sign. These values are all in terms of a division of the scale, which will presently be shown to be about 0.8 magnitudes.

TABLE I
DATA RELATING TO TESTS

Observer	Date			Light	Time	Mean Difference	Average Difference
	<i>y</i>	<i>m</i>	<i>d</i>		<i>m</i>		
A	1903	1	15, 16	Daylight	47	+ .06	.17
B (1)	"	1	16	"	25	- .11	.26
B (2)	1913	10	28, 29	"	26	- .03	.20
D	1903	1	16, 17	"	45	- .15	.30
F (1)	"	1	19	"	52	- .04	.14
F (2)	1913	9	11, 13	Electric light	50	+ .01	.14
G	1903	2	11	Daylight	57	+ .06	.21
H	"	6	9	"	32	- .05	.25
I	1913	7	1	"	36	- .08	.25
J	"	9	3, 5	Electric light	34	+ .14	.24
N	"	9	3, 5	"	45	- .04	.11
P	"	9	4, 8	"	27	- .01	.10
Q	"	9	4, 30	"	35	+ .03	.15
R	"	10	7, 15	"	44	- .03	.20

Table II contains the summary of the measures. The first column gives an arbitrary designation of the star, the numeral indicating whether the image was made by the first, second, third, or fourth exposure. Only those images measured by all the observers are included. The second column gives the designation of the star as employed in Table IV of Harvard Annals 71, No. 3. The third column gives the mean of the fourteen measures, and is followed by the residuals, expressed in tenths of a division, for the individual observers. The last column gives the average deviation for the fourteen measures, expressed also in tenths of a division. Images i 2, and i 3 have the largest average deviations. Images b 1 and a' 1 stand next. The stars b and i, which are more distant from the center of best focus, have somewhat diffuse images on this plate, but were included to show how different observers would react to images which were not concentrated. At the foot of the table are the means of the results. The mean of these taken without respect to sign is ± 0.11 divisions. Subtracting each mean from the twenty-four values above it, we find the average deviation. These are indicative of the value of the observations of the several observers.

Another consideration is the ability of the observer to measure bright and faint images equally well. As a test, the star images have been divided into six groups of four each, as follows: I.—i 2, h 2, g 3, a 1; II.—b 1, i 3, b' 4, h 3; III.—j 2, a' 1, j 3, b' 1; IV.—c 4, j' 2, k 2, j' 3; V.—g 4, h 4, k 3, e 1; VI.—l 2, g 1, i 4, j 4.

TABLE II
SUMMARY OF MEASURES

Star	No.	Mean	A	B	B	D	F	F	G	H	I	J	N	P	Q	R	A.D.
a 1	1	2.4	0	2	4	6	2	2	4	4	3	2	4	6	0		3
a' 1	2	3.5	1	1	3	4	3	3	3	5	5	1	7	3	14	2	4
b 1	5	2.4	3	4	5	8	2	3	4	4	1	0	3	4	14	1	4
b' 1	7	4.7	1	1	2	0	1	3	0	1	0	1	1	1	9	1	2
e 1	11	6.7	2	2	1	1	3	3	1	2	1	7	1	5	1	0	2
g 1	16	7.7	2	0	3	1	1	1	1	4	1	1	1	1	1	2	1
h 2	17	1.8	3	0	4	3	1	3	0	2	2	6	2	1	8	1	3
i 2	19	1.5	4	5	8	5	5	3	5	5	3	9	0	3	21	3	6
j 2	23	3.3	1	3	1	1	1	1	0	3	1	5	0	4	3	1	2
j' 2	27	4.8	0	2	3	2	2	3	3	1	2	1	2	2	9	1	2
k 2	29	5.6	0	1	1	3	2	2	1	2	1	1	0	1	6	4	2
l 2	31	7.2	2	2	3	2	1	1	3	0	1	1	1	1	0	4	2
g 3	16	1.9	2	1	0	3	1	1	1	1	5	5	2	3	2	2	2
h 3	17	2.8	0	4	2	2	1	2	0	6	2	4	0	0	0	2	2
i 3	19	2.7	5	5	4	7	5	1	9	10	2	12	6	1	15	1	6
j 3	23	4.3	1	1	2	3	4	2	1	1	3	1	1	1	5	1	2
j' 3	27	5.7	1	1	2	3	2	3	4	0	1	1	1	0	6	1	2
k 3	29	6.5	1	1	1	3	3	2	0	3	1	3	0	1	1	1	2
b' 4	7	2.7	1	0	3	4	2	3	3	7	8	3	1	5	1	0	3
e 4	11	4.7	2	3	3	6	0	1	2	3	5	2	1	1	1	1	2
g 4	16	5.7	1	1	3	1	3	1	1	2	1	1	1	1	2	1	1
h 4	17	6.3	1	1	3	1	1	1	1	1	2	0	1	1	1	1	1
i 4	19	7.7	2	5	1	2	1	2	1	1	0	0	1	0	1	1	1
j 4	23	7.8	2	0	2	4	3	0	0	2	4	4	0	2	0	0	2
Means			-1	-1	+1	-1	0	0	-1	-2	+2	+2	0	+2	-1	+2	
A.D.			.14	.20	.23	.30	.21	.19	.22	.25	.20	.27	.15	.17	.51	.11	

The mean readings for the six groups in terms of the scale are 1.9, 2.6, 4.0, 5.2, 6.3, and 7.6. The means of the residuals from Table II, grouped thus according to brightness, are found in Table III, following the letter of the observer in the first column. The eighth column gives the average deviation, in terms of a division, for each observer. The last column gives the range in tenths of a division of the scale. At the foot of the table the average deviation for each group according to brightness is given. The measures are more accordant as the images become fainter.

From the data given in Table II it is possible to determine the value of a division of the scale in magnitudes, valid for this particular investigation. Plotting these measures against the provisional magnitudes (H. A. 71, 53, 1917), we find the average value of 0.80 magnitudes. Assigning to Star a, Alcyone, the brightness

TABLE III
MEASURES ACCORDING TO BRIGHTNESS

Observer	1.9	2.6	4.0	5.2	6.3	7.6	A.D.	Range
A	-2	0	+1	-1	-1	-2	.09	3
B (1)	-2	-3	0	0	-1	-1	.09	3
B (2)	0	-1	+2	0	+1	+2	.10	3
D	-4	-5	0	0	+2	0	.22	7
F (1)	+1	+2	0	-2	-1	-1	.12	4
F (2)	+2	+1	-2	0	0	0	.09	4
G	0	-4	0	+2	0	0	.12	6
H	-3	-7	-2	0	0	-1	.19	7
I	+2	+2	+2	+2	0	+1	.07	2
J	+4	+5	+2	+2	-1	+2	.14	6
N	0	+2	+2	-1	0	0	.10	3
P	+3	+2	+2	+1	+1	0	.08	3
Q	+1	+7	-8	-5	0	0	.38	15
R	-1	-1	+1	+2	+1	+2	.11	3
A.D.	.18	.30	.17	.13	.06	.09		

given in Harvard Annals **76**, we derive the following magnitudes: Star 1, 2.88; 2, 3.76; 7, 4.72; 11, 6.32; 16, 7.12; 17, 7.72; 23, 8.92; 27, 10.08; 29, 10.72; 31, 12.00. Stars 5 and 19 have been omitted on account of their diffuse images.

The film of the plate C 14146 became more or less abraded by the rubbing of the scale over the surface. On December 20, 1913, it was varnished for the sake of protection. Measures made by two observers before and after the operation indicate that the images appeared about 0.08 divisions fainter after varnishing.

For examples of the use of the test plate, some recent measures have been made by several observers. The results are contained in Table IV, which gives quanti-

TABLE IV
EXAMPLE OF TESTS

Observer	Time	Mean Diff.	Average Diff.	Mean	A. D.	Brightness						A. D.	Range
						1.9	2.6	4.0	5.2	6.3	7.6		
1	36	-.04	.35	+2	.23	+2	+2	+4	0	+1	+2	.09	4
2	43	-.03	.17	-3	.23	-5	-5	-4	-4	-2	+1	.18	6
3	34	+.05	.33	+1	.20	+1	+3	0	0	0	0	.09	3
4	51	+.05	.15	0	.32	-4	-5	-2	+2	+2	+3	.30	8

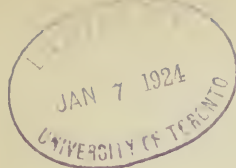
ties similar to those in Tables I, II, and III. Of the four observers, it is apparent that No. 3 combines most good qualities. In the first place, the time used for

measuring is least. Although the average of the differences between the first and the second sets of measures is larger than for others, the small average deviation in the sixth column compensates. The facility in measuring images of varying brightness is slightly better than that of No. 1. The figures show good uniformity with an accuracy of about 0.07 magnitudes. From a test of this character it is possible to determine not only the relative skill in observing, but also the ability to understand and execute a new line of procedure and the sense of neatness and precision in recording observations.

SUMMARY

A photograph of stars for measurement and a scale of graded photographic images are the essentials of the test described. By means of measures made in the same way by a group of observers, it is found what may be considered a fair average performance. The relative skill of the individual is thus determined. Many persons with little or no experience of the sort apparently are able to engage effectively in the work of measuring photographs.

OCTOBER 25, 1923.



HARVARD COLLEGE OBSERVATORY

CIRCULAR 250

LONG PERIOD VARIABLES. PREDICTED MAXIMA AND MINIMA, 1924

BY LEON CAMPBELL

Predicted dates of maxima and minima for variable stars of long period are given in the following table. The successive columns contain the designation number, the name, and the dates for 369 variables.

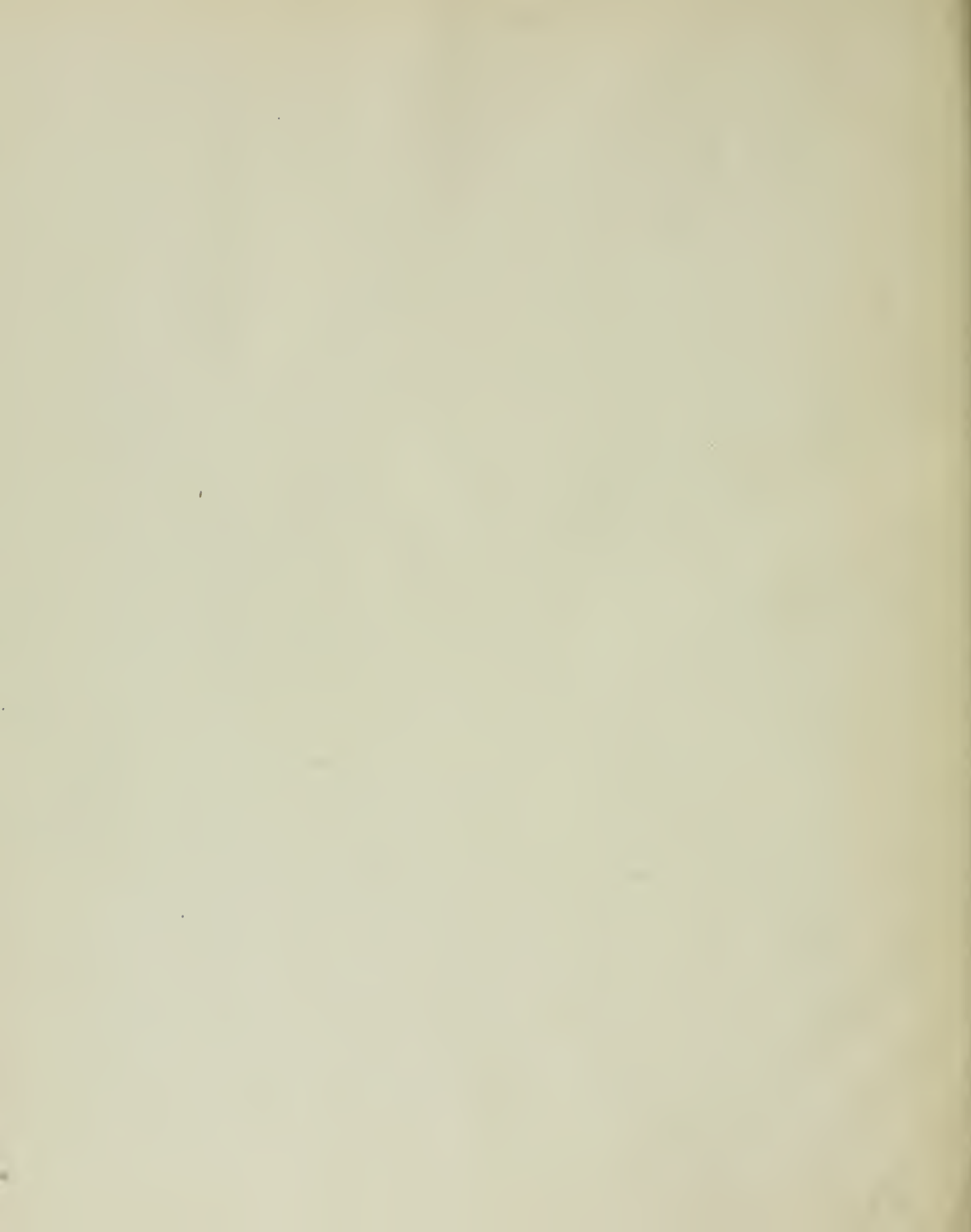
Des.	Name	1924		Des.	Name	1924		Des.	Name	1924	
		Max.	Min.			Max.	Min.			Max.	Min.
		<i>m d</i>	<i>m d</i>			<i>m d</i>	<i>m d</i>			<i>m d</i>	<i>m d</i>
000339	V Scl	10 1	5 25	011712	U Psc	8 20	11 2	032043	Y Per	...	11 22
001032	S Scl	12 18	6 25	012350	RZ Per	3 17	10 19	032335	R Per	6 23	3 1
001046	X And	9 25	5 23	012502	R Psc	5 2	11 17	"	"	...	9 27
001726	T And	3 22	8 3	013238	RU And	3 7	7 3	035124	T Eri	5 8	1 1
"	"	12 28	...	"	"	11 4	...	"	"	...	9 9
001755	T Cas	11 22	3 30	013338	Y And	3 30	7 27	040725	W Eri	1 9	9 9
001838	R And	4 30	12 30	"	"	11 3	...	042209	R Tau	7 8	1 10
001862	S Tuc	3 21	8 2	014958	X Cas	9 20	1 10	"	"	...	11 30
"	"	11 16	...	015354	U Per	10 3	5 24	042215	W Tau	3 11	6 27
001909	S Cet	9 19	4 14	015912	S Ari	3 3	7 23	"	"	12 2	...
002438a	T Scl	7 13	3 31	"	"	12 20	...	042309	S Tau	8 27	1 16
"	"	...	10 19	021024	R Ari	5 18	2 25	043065	T Cam	6 13	1 5
002546	T Phe	5 3	10 1	"	"	11 20	8 29	043208	RX Tau	6 3	10 15
003179	Y Cep	2 17	8 12	021143a	W And	12 5	6 28	043263	R Ret	3 28	8 17
004047	U Cas	2 23	7 31	021281	Z Cep	9 3	5 9	043274	X Cam	1 18	3 22
"	"	11 25	...	021403	o Cet	1 29	9 15	"	"	6 7	8 11
004132	RW And	12 24	7 18	"	"	12 26	...	"	"	10 26	12 30
004435	V And	6 7	2 9	022000	R Cet	3 26	1 5	043562	R Dor	6 8	9 24
"	"	...	11 1	"	"	9 9	6 20	043738	R Cae	4 2	12 2
004435	X Scl	3 31	8 6	"	"	...	12 4	044617	V Tau	4 30	2 12
"	"	12 6	...	022150	RR Per	3 31	10 29	"	"	10 17	7 31
004533	RR And	10 21	5 24	022426	R For	11 15	3 21	045307	R Ori	8 30	4 1
004746a	RV Cas	10 21	6 15	022813	U Cet	2 27	7 2	045514	R Lep	...	6 9
004958	W Cas	5 8	11 24	"	"	10 20	...	050003	V Ori	3 29	7 26
005475	U Tuc	1 19	6 5	022980	RR Cep	8 27	3 30	"	"	12 21	...
"	"	10 3	...	023133	R Tri	4 1	8 26	050022	T Lep	1 28	7 16
010102	Z Cet	4 21	1 24	"	"	12 24	...	050848	S Pic	1 1	10 8
"	"	10 23	7 27	024356	W Per	12 6	5 9	050953	R Aur	2 22	11 6
010630	U Scl	10 5	6 19	025050	R Hor	10 21	5 9	051247	T Pic	2 26	6 15
010940	U And	5 16	12 12	025751	T Hor	5 14	2 2	"	"	9 19	...
011041	UZ And	1 5	7 3	"	"	12 18	9 7	051533	T Col	4 24	1 6
"	"	11 10	...	030514	U Ari	6 3	12 8	"	"	12 5	8 18
011208	S Psc	11 26	4 28	031401	X Cet	1 31	4 18	052034	S Aur	10 19	...
011272	S Cas	...	8 22	"	"	7 25	10 11	052036	W Aur	7 18	4 10
011712	U Psc	2 29	5 13	032043	Y Per	7 10	3 18	052404	S Ori	12 24	6 5

Des.	Name	1924		Des.	Name	1924		Des.	Name	1924	
		Max.	Min.			Max.	Min.			Max.	Min.
053068	S Cam	m d 9 21	m d 7 12	072708	S CMi	m d 4 25	m d 9 16	122532	T CVn	m d 4 16	m d 9 1
053531	U Aur	9 6	3 18	072811	T CMi	9 19	5 12	122803	Y Vir	7 9	3 24
054331	S Col	6 3	1 15	072820b	Z Pup	...	10 31	"	"	...	10 28
"	"	...	12 10	090024	S Pyx	6 23	3 14	122854	U Cen	4 3	7 31
054615a	Z Tau	12 15	5 12	"	"	...	10 6	"	"	11 8	...
054629	R Col	7 1	3 3	090425	W Cnc	1 24	9 17	123160	T UMa	2 8	7 9
054920	U Ori	8 28	4 7	091868	RW Car	6 24	2 16	"	"	10 22	...
054974	V Cam	8 8	2 25	092551	Y Vel	5 21	...	123307	R Vir	1 15	3 25
055353	Z Aur	2 4	3 25	092962	R Car	1 7	6 29	"	"	6 8	8 17
"	"	5 24	7 13	"	"	11 11	...	"	"	10 31	...
"	"	9 11	10 31	093014	X Hya	6 6	2 9	123459	RS UMa	7 11	3 27
055686	R Oct	12 30	7 1	"	"	...	12 10	"	"	...	12 12
060450	X Aur	5 31	2 29	093178	Y Dra	6 17	2 7	123961	S UMa	1 26	5 30
"	"	11 10	8 10	"	"	...	12 30	"	"	9 8	...
061647	V Aur	12 10	2 17	093934	R LMi	3 11	10 25	124204	RU Vir	1 25	8 24
073173	S Vol	1 1	7 13	094023	RR Hya	9 22	3 29	124606	U Vir	3 24	7 6
073508	U CMi	1 1	8 17	094211	R Leo	6 24	2 1	"	"	10 17	...
073723	S Gem	6 9	2 7	"	"	...	12 10	130212	RV Vir	1 1	8 12
"	"	...	11 26	094953	Z Vel	11 18	5 18	"	"	10 2	...
074241	W Pup	4 5	2 3	095421	V Leo	3 17	8 16	131283	U Oct	8 22	4 6
"	"	8 4	6 3	"	"	12 14	...	132202	V Vir	7 1	3 25
"	"	12 3	10 2	095458	RR Car	2 14	5 13	"	"	...	11 30
074323	T Gem	6 9	1 23	"	"	7 16	10 13	132422	R Hya	3 11	10 1
"	"	...	11 6	095563	RV Car	12 16	...	132706	S Vir	4 7	10 15
081112	R Cnc	3 22	10 3	"	"	4 16	11 24	133155	RV Cen	9 21	2 6
081617	V Cnc	4 19	9 9	100661	S Car	3 21	1 4	133273	T UMi	4 23	10 21
082476	R Cha	6 26	2 29	"	"	8 17	6 1	133633	T Cen	3 20	2 7
083019	U Cnc	3 25	9 16	"	"	...	10 28	"	"	6 18	5 7
083350	X UMa	8 26	5 4	101058	Z Car	10 26	6 3	"	"	9 16	8 5
084803	S Hya	5 31	1 25	101153	W Vel	10 3	4 24	"	"	12 15	11 3
"	"	...	10 6	103270	RZ Car	9 1	5 26	132436	RT Cen	5 30	1 31
085008	T Hya	9 19	4 24	103769	R UMa	3 27	9 23	"	"	...	10 5
085120	T Cnc	...	7 18	104628	RS Hya	7 31	3 3	134440	R CVn	2 7	7 24
061702	V Mon	3 9	9 19	104814	W Leo	3 29	12 22	134536	RX Cen	9 15	5 26
063159	U Lyn	...	9 6	110506	S Leo	3 29	6 18	134677	T Aps	4 10	1 15
063558	S Lyn	4 4	9 13	"	"	10 5	12 25	"	"	...	10 11
064030	X Gem	7 4	2 20	111561	RY Car	9 15	2 20	135908	RR Vir	1 3	5 16
"	"	...	11 8	111661	RS Cen	4 12	1 29	"	"	8 7	12 19
065111	Y Mon	1 13	5 6	"	"	9 24	7 12	140113	Z Boo	6 17	3 11
"	"	8 29	12 21	"	"	...	12 24	"	"	...	12 20
065208	X Mon	4 19	1 31	114441	X Cen	8 30	5 8	140512	Z Vir	2 27	1 1
"	"	9 14	6 27	115058	W Cen	3 16	6 27	"	"	...	10 31
"	"	...	11 22	"	"	10 4	...	140528	RU Hya	4 9	11 2
065355	R Lyn	7 11	1 23	115919	R Com	6 6	2 1	140959	R Cen	11 2	6 17
070109	V CMi	10 18	6 5	120012	SU Vir	5 16	2 22	141567	U UMi	2 13	8 5
070122a	R Gem	11 13	7 23	"	"	12 7	9 14	141954	S Boo	1 18	6 19
070310	R CMi	11 26	6 30	120905	T Vir	6 13	2 28	"	"	10 14	...
070772	R Vol	12 1	5 5	121418	R Crv	1 5	6 29	142205	RS Vir	3 7	10 25
071201	RR Mon	12 5	6 21	"	"	11 18	...	142539	V Boo	5 22	1 13
071713	V Gem	8 18	4 26	122001	SS Vir	10 7	5 2	"	"	...	9 27

Des.	Name	1924		Des.	Name	1924		Des.	Name	1924	
		Max.	Min.			Max.	Min.			Max.	Min.
142584	R Cam	<i>m d</i> 8 22	<i>m d</i> 6 9	160325	SX Her	<i>m d</i> 8 26	<i>m d</i> 10 26	174551	U Ara	<i>m d</i> 10 9	<i>m d</i> ...
143227	R Boo	6 1	2 15	"	"	12 6	...	175111	RT Oph	3 11	12 22
"	"	...	9 25	160519	W Sco	5 10	1 25	175458a	T Dra	12 4	6 17
143417	V Lib	4 15	9 1	"	"	12 18	9 3	175519	RY Her	7 5	4 2
144918	U Boo	2 12	6 15	160625	RU Her	7 7	...	"	"	...	11 10
"	"	8 6	12 8	161122a	R Sco	4 13	1 18	175654	V Dra	3 17	8 12
145254	Y Lup	4 1	12 18	"	"	11 22	8 28	"	"	12 22	...
150018	RT Lib	3 27	8 6	161122b	S Sco	3 7	6 15	180363	R Pav	3 5	7 3
150519	T Lib	7 21	4 4	"	"	8 31	12 9	"	"	10 21	...
"	"	...	11 28	161138	W CrB	5 12	1 28	180531	T Her	3 12	6 3
150605	Y Lib	5 9	6 13	"	"	...	9 22	"	"	8 24	11 15
"	"	...	12 23	161607	W Oph	1 15	7 27	180565	W Dra	7 30	4 13
151520	S Lib	6 13	2 27	"	"	12 10	...	180666	X Dra	3 4	6 30
"	"	12 23	9 7	162112	V Oph	5 16	10 25	"	"	11 16	...
151714	S Ser	8 21	2 23	162119	U Her	4 20	12 25	181031	TV Her	6 4	1 25
151731	S CrB	12 16	8 20	162319	Y Sco	8 1	2 22	"	"	...	11 25
151822	RS Lib	2 19	6 17	162807	SS Her	3 11	1 31	181103	RY Oph	2 25	5 28
"	"	9 23	...	"	"	6 25	5 16	"	"	7 27	10 28
152714	RU Lib	3 2	8 26	"	"	10 9	8 30	181136	W Lyr	3 9	6 20
152849	R Nor	4 27	2 8	"	"	...	12 14	"	"	9 21	...
"	"	...	11 23	162815	T Oph	3 30	11 25	182133	RV Sgr	4 14	10 1
153020	X Lib	2 18	5 20	162816	S Oph	1 19	6 25	182224	SV Her	5 27	2 4
"	"	7 30	10 30	"	"	9 9	...	"	"	...	10 1
153215	W Lib	3 20	7 14	163137	W Her	8 22	4 24	182306	T Ser	1 26	6 25
"	"	10 11	...	163266	R Dra	4 10	8 30	183149	SV Dra	7 1	4 22
153378	S UMi	7 19	10 9	"	"	12 12	...	183225	RZ Her	10 29	6 11
153620	U Lib	5 26	2 22	164319	RR Oph	3 19	9 9	183308	X Oph	2 13	7 28
"	"	...	10 5	164715	S Her	7 21	2 24	184134	RY Lyr	2 29	8 22
153654	T Nor	7 21	4 2	164844	RS Sco	5 23	11 12	184243	RW Lyr	4 2	...
"	"	...	12 2	165030	RR Sco	5 22	1 18	185032	RX Lyr	7 7	3 29
154536	X CrB	5 13	1 22	"	"	...	10 22	"	"	...	12 3
"	"	...	9 17	165631	RV Her	7 31	5 30	185512a	ST Sgr	3 30	11 8
154615	R Ser	2 19	9 18	"	"	...	12 20	185634	Z Lyr	4 15	9 21
154639	V CrB	10 27	5 22	165636	RT Sco	8 25	3 9	185737	RT Lyr	7 13	3 25
154715	R Lib	8 1	5 20	170215	R Oph	7 7	3 7	"	"	...	11 30
154736	R Lup	3 27	7 15	170627	RT Her	6 15	2 23	190108	R Aql	4 9	11 20
"	"	11 16	...	170833	RW Sco	5 9	1 6	190529a	V Lyr	5 17	1 28
155018	RR Lib	1 22	7 5	171401	Z Oph	1 4	7 22	190925	S Lyr	10 24	5 2
"	"	10 25	...	"	"	12 18	...	190933a	RS Lyr	6 7	1 29
155229	Z CrB	6 4	2 19	171723	RS Her	3 5	6 23	"	"	...	11 22
"	"	...	10 27	"	"	10 11	...	190941	RU Lyr	11 18	6 1
155823	RZ Sco	6 12	4 8	172486	S Oct	4 19	1 3	190967	U Dra	9 3	3 22
"	"	11 17	9 13	"	"	...	9 18	191007	W Aql	5 4	...
160021	Z Sco	12 10	6 23	172809	RU Oph	2 20	6 20	191017	T Sgr	7 3	...
160118	R Her	1 23	7 19	"	"	9 8	...	191019	R Sgr	8 25	5 3
"	"	12 6	...	173543	RU Sco	12 4	5 6	191319	S Sgr	3 5	6 25
160210	U Ser	8 13	4 17	174135	SV Sco	7 29	4 6	"	"	10 21	...
"	"	...	12 11	"	"	...	12 18	191321	Z Sgr	3 25	12 24
160325	SX Her	2 4	4 5	174162	W Pav	6 30	3 19	191331	SW Sgr	4 10	9 18
"	"	5 16	7 16	174551	U Ara	2 28	7 5	191637	U Lyr	3 22	10 5

Des.	Name	1924		Des.	Name	1924		Des.	Name	1924	
		Max.	Min.			Max.	Min.			Max.	Min.
192928	TY Cyg	<i>m d</i> 10 13	<i>m d</i> 4 28	203429	R Mic	<i>m d</i> 9 12	<i>m d</i> 7 5	215605	V Peg	<i>m d</i> ...	<i>m d</i> 12 11
193311	RT Aql	5 30	1 27	"	"	...	11 20	215828	S PsA	2 26	7 16
193449	R Cyg	8 18	3 19	203611	Y Del	7 19	2 10	"	"	11 23	...
193509	RV Aql	2 4	6 17	203816	S Del	5 24	9 21	215934	RT Peg	1 15	5 14
"	"	9 9	...	203847	V Cyg	...	7 31	"	"	8 2	11 30
193972	T Pav	1 27	6 1	203905	Y Aqr	9 4	3 31	220412	T Peg	6 3	1 1
"	"	9 27	...	204016	T Del	9 13	4 26	220613	Y Peg	1 19	5 4
194048	RT Cyg	3 10	6 13	204104	W Aqr	4 17	11 16	"	"	8 14	11 28
"	"	9 16	12 20	204215	U Cap	4 30	1 19	220714	RS Peg	12 12	9 3
194348	TU Cyg	4 26	2 2	"	"	11 18	8 8	221230	R PsA	2 4	7 1
"	"	11 30	9 7	204318	V Del	9 19	3 10	"	"	11 24	...
194604	X Aql	1 23	8 20	204405	T Aqr	7 9	4 15	221321	X Aqr	5 24	10 18
194632	x Cyg	12 15	6 28	"	"	...	11 4	221938	T Gru	5 4	3 3
194659	S Pav	1 22	8 20	204846	RZ Cyg	1 3	4 24	"	"	9 18	7 18
194929	RR Sgr	11 8	6 23	"	"	9 27	...	"	"	...	12 2
195142	RU Sgr	5 11	1 27	204954	S Ind	2 11	10 9	221948	S Gru	...	8 16
"	"	...	9 25	205017	X Del	2 12	7 20	222129	RV Peg	9 28	4 26
195202	RR Aql	7 11	3 13	"	"	11 18	...	222439	S Lac	4 30	1 5
195308	RS Aql	11 29	6 17	205627	RR Cap	9 3	6 13	"	"	12 24	8 30
195849	Z Cyg	8 8	4 14	205923	R Vul	3 22	1 20	222867	R Ind	3 19	6 25
200212	SY Aql	2 21	10 5	"	"	8 6	6 5	"	"	10 21	...
200357	S Cyg	1 9	7 11	"	"	12 21	10 20	223462	T Tuc	5 5	9 10
"	"	11 28	...	210124	V Cap	2 29	8 12	223841	R Lac	2 13	7 31
200514	R Cap	2 8	9 15	"	"	11 30	...	"	"	12 8	...
200715a	S Aql	5 1	2 20	210129	TW Cyg	11 6	6 1	225120	S Aqr	4 4	10 1
"	"	9 24	7 16	210221	X Cap	5 28	1 13	225914	RW Peg	8 30	5 8
"	"	...	12 8	"	"	...	11 26	"	"	...	12 3
200747	R Tel	...	9 4	210382	X Cep	9 10	1 28	230110	R Peg	4 11	10 24
200812	RU Aql	9 9	5 8	210504	RS Aqr	5 15	1 19	230759	V Cas	8 12	5 2
200822	W Cap	3 29	7 7	"	"	12 17	8 20	"	"	...	12 17
"	"	10 23	...	210516	Z Cap	2 25	6 13	231425	W Peg	12 1	6 5
200906	Z Aql	2 1	4 10	"	"	8 24	12 11	231508	S Peg	4 10	9 9
"	"	6 9	8 17	210812	R Equ	5 21	1 26	232746	V Phe	3 7	7 12
"	"	10 16	...	"	"	...	10 13	"	"	11 13	...
200938	RS Cyg	1 25	9 1	210868	T Cep	6 30	12 22	233335	ST And	8 26	3 8
201008	R Del	1 25	7 3	210903	RR Aqr	3 6	6 13	233815	R Aqr	3 5	10 15
"	"	11 4	...	"	"	9 3	12 11	233956	Z Cas	9 11	1 25
201130	SX Cyg	6 22	1 14	211614	X Peg	1 1	3 30	235053	RR Cas	7 27	3 24
201139	RT Sgr	8 24	4 17	"	"	7 19	10 16	235150	R Phe	4 12	9 8
201437b	WX Cyg	9 29	4 4	211615	T Cap	4 15	1 3	235209	V Cet	6 13	2 14
201647	U Cyg	10 13	3 17	"	"	...	9 28	"	"	...	10 31
202240	U Mic	1 17	7 26	212030	S Mic	7 19	4 4	235265	R Tuc	8 14	4 26
"	"	12 15	...	"	"	...	11 3	235350	R Cas	2 14	11 14
202622	RU Cap	6 5	2 6	213678	S Cep	2 10	9 27	235525	Z Peg	1 23	7 31
202817	Z Del	10 7	5 28	214024	RR Peg	4 29	1 8	"	"	12 8	...
202954	ST Cyg	1 6	7 26	"	"	...	9 29	235715	W Cet	12 14	8 12
"	"	12 4	...	214247	R Gru	8 25	5 5	235855	Y Cas	5 25	...
203429	R Mic	4 27	2 18	215605	V Peg	6 16	2 12	235939	SV And	4 23	10 29





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